TMS

THE BUTTER INDUSTRY

Errata:

p. 218, Top, "butter scoring 38 points" should read: butter scoring 39 points.

p. 237, Reference 1. "1935" should read: "1928."

p. 588, Second line, "one-fifth" should read: four-fifths.

p. 597, "Irradication" should read: Irradiation.

THE BUTTER INDUSTRY

PREPARED FOR

FACTORY, SCHOOL AND LABORATORY

THIRD EDITION

REWRITTEN AND ENLARGED

BY

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I am indebted also to the many individuals and firms in the field of dairy equipment and supplies, for their generous co-operation in providing a wealth of valuable information, in supplying many useful illustrations for the text, and who enhanced the service of this volume to the industry by their esteemed advertisements.

PREFACE

This book is written for the student in butter making, the research worker on butter problems, the pure food and law-enforcing official and the butter maker and creamery operator.

It is organized for use as text for classroom instruction, aiming to present the fundamentals of technical and operating problems in suitable sequence, to convey to the student a tangible picture of the industry as a whole, and to provide him with a dependable source of important facts for later reference.

It is intended to serve as a stimulus to the research worker, calling to his attention the real problems of the industry and suggesting new problems and new angles of old problems, that are awaiting his study and solution.

It is meant to facilitate acquaintance on the part of pure food officials and law-enforcing agencies with industry practices, and to promote their understanding of the possibilities and limitations of helpful regulatory control.

Above all, it appeals to the busy butter maker and creamery operator, who are in need, not of references and theories, but of dependable facts, scientifically sound and proven by practical experience, presented in a manner that will assist them in the constructive solution of their current problems.

The text of this new "Third" edition is the composite result of painstaking study, digestion and assimilation of the vast array of available scientific data and of the latest commercial developments dealing with improved equipment, methods and product, accomplished on this continent and abroad, combined with and made useful through the acid test of practical experience in plant operation under diverse economic and climatic conditions, character of raw materials, methods of manufacture and means and conditions of distribution.

O. F. Hunziker

La Grange, Illinois,
June, 1940

INTRODUCTION

Butter Fat the Most Valuable Constituent of Milk.—Butter making constitutes the earliest effort of man in the manufacture of dairy products. This fact suggests the early recognition among the keepers of milk-giving animals, of the superior value of the fat of milk. This recognition has continued through the ages and its justification is substantiated by the latest revelations of the science of nutrition. While each of the solid ingredients of milk—the fat, the proteins, the carbohydrates and the ash—are recognized to be of a quality superior to corresponding groups of similar nutrients derived from other sources, the fat of milk, because of its proven superiority in digestibility, vitamin properties and palatability, ranks first in value and the economic and commercial value of milk is primarily adjudged, aside from its sanitary standard, on the basis of its fat content.

Magnitude of Butter Industry.—Butter being essentially a concentrate of the fat of milk, the making of butter exceeds by a wide margin all other branches engaged in the manufacture of dairy products. The World's butter production is estimated at approximately 7,000,000,000 to 8,000,000,000 lbs. annually. Of this volume about 2,300,000,000 lbs. is made in the United States. Over 42 per cent of the total volume of milk produced in this country is utilized for butter manufacture, and approximately 75 per cent of the milk used for the manufacture of dairy products, is made into butter.

Butter the Balance Wheel of Dairy Industry.—Butter serves as the safety valve for the entire dairy industry. It absorbs the surplus milk supply above market requirements for other dairy products. Milk not required by the demand for these products overflows into the creamery, is skimmed and the cream churned into butter. When the milk supply for other dairy products runs short of their demand, milk normally intended for butter is diverted into the channels where needed. The butter industry thus provides a never-failing balance wheel that takes up the slack in the relationship of supply and demand of all other dairy products.

Importance of Butter Industry.—The butter industry puts to profitable use hundreds of millions of dollars worth of capital that might otherwise lie idle and unproductive. It employs hundreds of thousands of wage earners assuring them and their families of a living wage. It supplies a ready market for the

product of the farmer who milks cows, regardless of size of herd or of location of farm. It returns to the farmer ready cash, and pays him a larger share of the consumer's dollar than any other major farm product. It makes available to him an abundance of valuable by-products in the form of skim milk and buttermilk, that provide the most suitable basis for a wholesome and economical feed ration for his calves, pigs, hogs and chickens, increasing his farm income and conserving the fertility of his land.

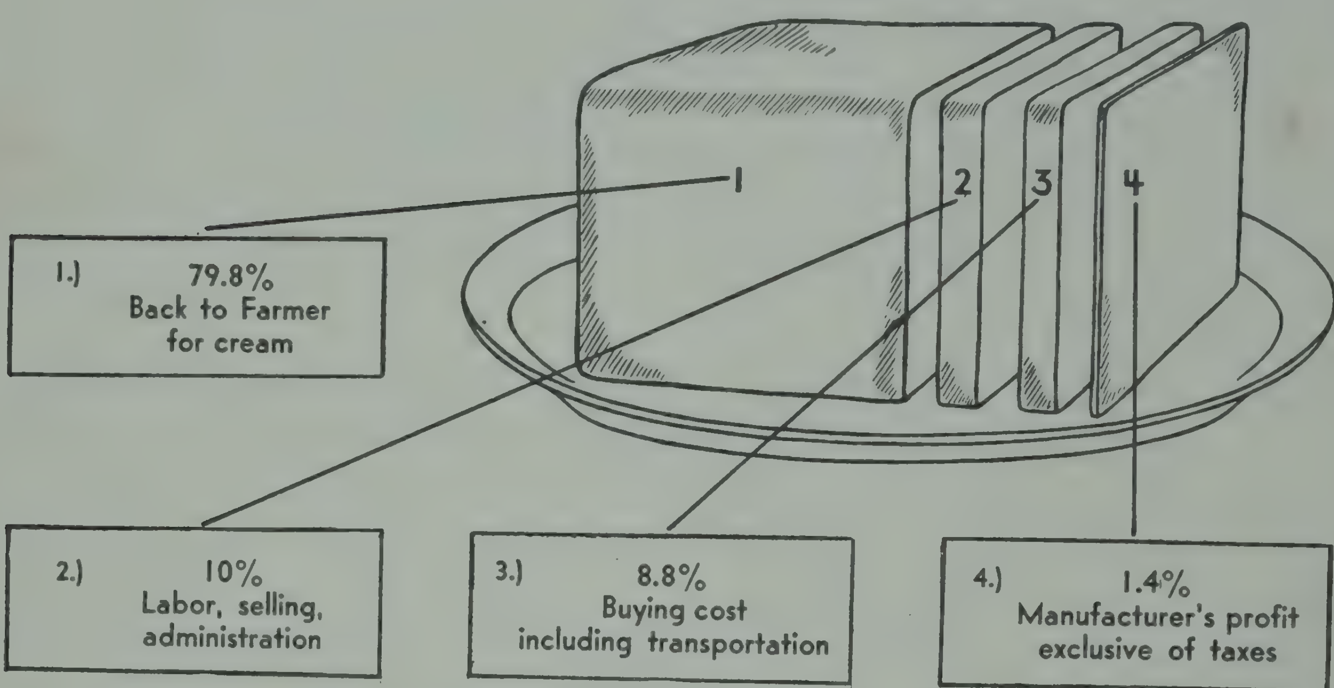

Fig. 1. Disposition of consumer's butter dollar, on basis of wholesale price
Statistics by courtesy of American Butter Institute

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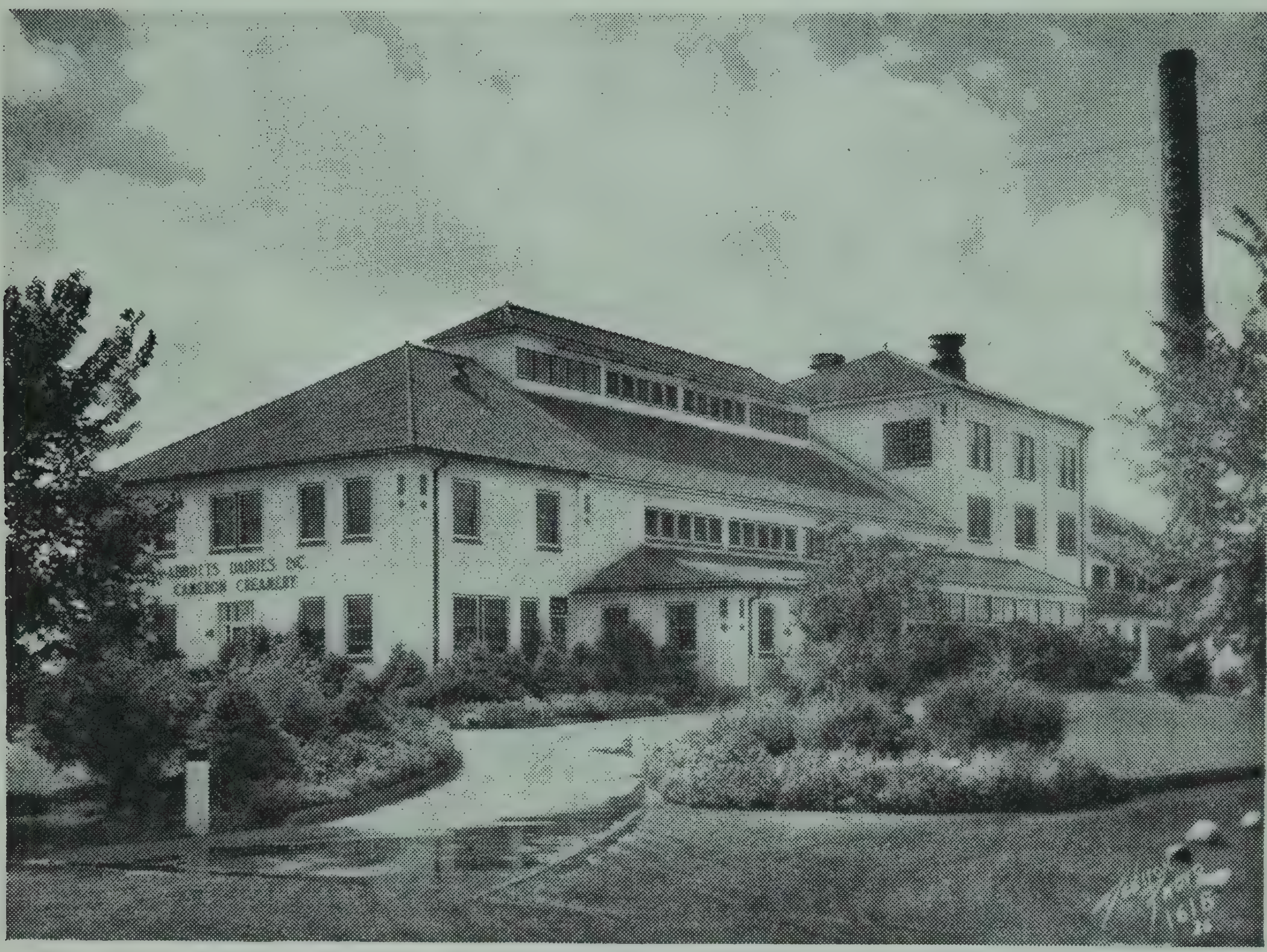


Fig. 2. A successful modern creamery
Courtesy of Mr. Guy Speirs, General Manager, Cameron Creamery, Abbotts Dairies, Inc., Cameron, Wisconsin

CHAPTER I

HISTORY AND DEVELOPMENT OF BUTTERMAKING

Early History.—The art of buttermaking dates back to times immemorial. Reference to the use of butter for sacrificial worship, for medicinal and cosmetic purposes, and as a food for man, may be found chronicled long before the Christian Era. Documentary manifestations indicate that, at least on the continents of the Old World, the taming and domestication of animals constituted the earliest beginnings of human civilization and culture. There is good reason to believe, therefore, that the milking of animals and the origin of buttermaking ante-

date the beginning of organized and permanent recording of human activities.

In contrast to the earliest existence of diverse types of milk-giving animals on the vast expanses of the Old World, it appears that there never existed a typical pastoral people on the continents of the Western Hemisphere. According to the researches of Humboldt[1] and others, the early European explorers found nowhere in North America, in South America, nor in Australia and New Zealand tangible evidence of the presence or of the husbandry of milk-giving animals, or of the use of milk from animals for human food.

The earliest records relating to buttermaking by the Ancients, and the multitude of annals that refer to its development, from the prehistoric evidences down through the later centuries, convey the inevitable impression that the making of butter on the continents of the Old World originated and gained momentum among the peoples dwelling in the cooler climes, while in the warmer territories the churning of butter has received attention only in much more recent times.

It is conceivable that in the background of this manifested localization of buttermaking in the cooler regions of the temperate zone lies the fact that, while butter can be churned direct from milk, the economically really practical procedure lies in skimming the milk and churning the cream. In the absence of knowledge of centrifugal separation among the Ancients, gravity creaming provided the only available means for churning cream. But even gravity creaming is possible only with milk that has retained the physical character of freshly drawn milk. In the case of curdled milk, for instance, gravity creaming is impossible. The fat globules cannot rise to the surface. The layer of cream does not form. Since prolonged exposure to warmth is normally accompanied by changes that cause milk to curdle and, since gravity creaming occupies at best from 24 to 48 hours, or longer, gravity creaming, which was the only known method for skimming the milk and producing cream, available to the Ancients, failed to serve the purpose in the warmer regions.

The assumption, therefore, is that the above may be one of the fundamental reasons, why the making of butter in the early days of civilization, and even down to more recent times prior to the advent of the centrifugal cream separator, was

confined to latitudes, or altitudes, or both, that provide a climate sufficiently cool for successful gravity creaming. That it was not lack of milk-giving animals, nor absence of milk supply, that prevented the making of butter in the warmer countries, appears evident from the fact, that in many of these countries cheese was well known in the days of the Ancients, its production made rapid progress and later reached a high state of development.

The industry is indebted for much of its present knowledge of the origin and of the early history of buttermaking to the pioneer German dairy scientist and noted historian, Benno Martiny (1836-1923), for his untiring, painstaking, exhaustive and unbiased search among the literary and historical archives relating to the Ancient peoples of the Earth.

Martiny, in his treatise "Die Milch"[2] and later in his unique volume on the history of the churn, entitled "Kirne und Girbe"[3], records a multitude of quotations and passages relating to the making and use of butter as far back as 2,000 years before Christ. He makes reference to the early Indians of Asia, the

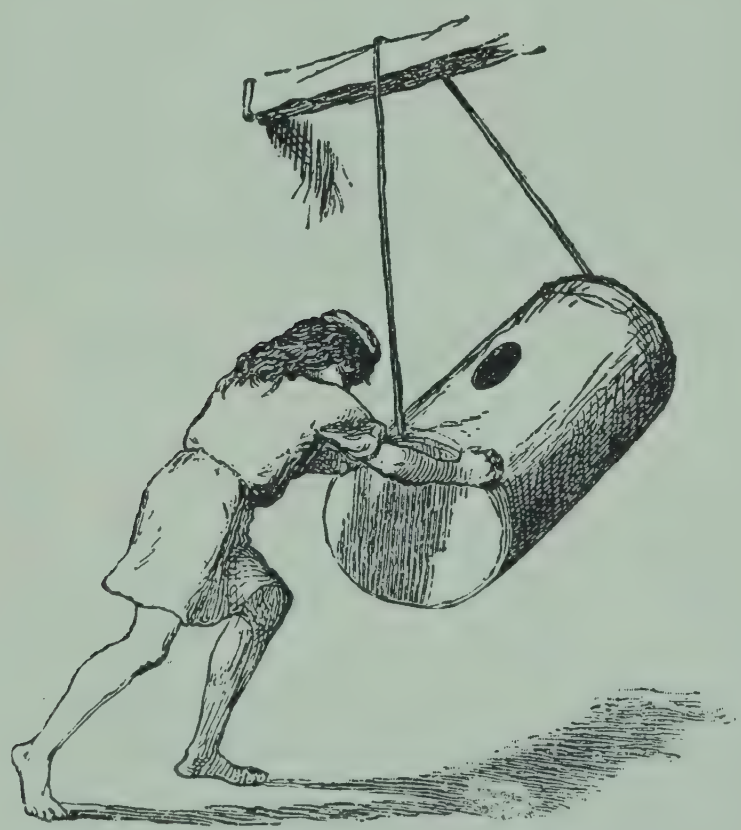


Fig. 3. Swinging churn of Asia Minor

Hebrews, the Arabs, the Egyptians, the Persians, the Greeks, the Romans, the Teutons, etc., as well as to the status of buttermaking during the middle ages and the later centuries.

It was the Vedas, the sacred songs of the dwellers of

Asiatic India, which chronicled the earliest traditions relating to buttermaking, dating back to 1,500-2,000 years before Christ. According to the Grihyasutras[1] of the 8th to the 9th century B. C., meaning the conventional rules of the domestic customs and rituals of the Hindoos of that period, when an Indian maiden was married, there was prepared for her a bridal feast consisting of milk, honey and butter. And one of the important rituals of the marriage ceremony was for the young bride to take a portion of the butter and grease with it the axel of the bridal carriage.

Fig. 4. Young Kathiawari women (India) churning butter in farmyard using a copper vessel with quirl
(Photo by James Sawders)

The Ancient Hebrews, because of references to butter in the early books of the Old Testament, have been credited with the use of butter and with knowledge of the art of buttermaking. Thus, the word butter appears in the Scriptures as far back as the book of Genesis 18:8, "And he (Abraham, 2150 B. C. according to Hommel), took butter, and milk, and the calf which he had dressed and set it before them." Again, one of the first Hebrew references to the making of butter is perhaps that by Solomon (993-953 B. C.), in Proverbs 30:33, "Surely the churning of milk bringeth forth butter."

It is possible that the Jews of Biblical times knew butter. However, there is considerable uncertainty regarding the accuracy of the translation that yielded the wording of the above

passages. In fact, the Hebrew words of the Old Testament fail to supply irrefutable proof of the correctness of the assumption that the product referred to actually was butter. The passage in Proverbs, for instance, which Luther translated as: "Surely

Fig. 5. Churning butter in skin of animals in Arabia

the churning of milk bringeth forth butter," literally says: when milk is pressed it bringeth forth "Chemah." From the account regarding Jael and Sisera, Judges IV. 19., as well as from numerous other passages, it is evident that the Hebrew people of those periods kept their milk in pouches of animal skins, in which it soured, fermented and curdled. The Hebrew word "Chemah" which Luther translated to mean butter, in all probability refers to sour, curdled wholemilk, rather than to butter, and "pressing the milk" probably has reference to pressing the pouch containing the thickened milk, causing the contents to discharge from the pouch, rather than to the churning of the milk into butter.

In the history of Ancient Greece, we find that the Greeks knew about butter. Thus, Solon (638-559 B. C.) refers to a "peculiar" fat obtained by agitating milk; Herodot (484-424 B. C.) described the making of butter by the Scythian hordes

from mare's milk; and Hippocrates (460-377 B. C.) stated that the Tracians made butter from cow's milk. Among the Romans who made great strides in agricultural development, cheese appears to have been more popular than butter. Yet, Plinius (23-

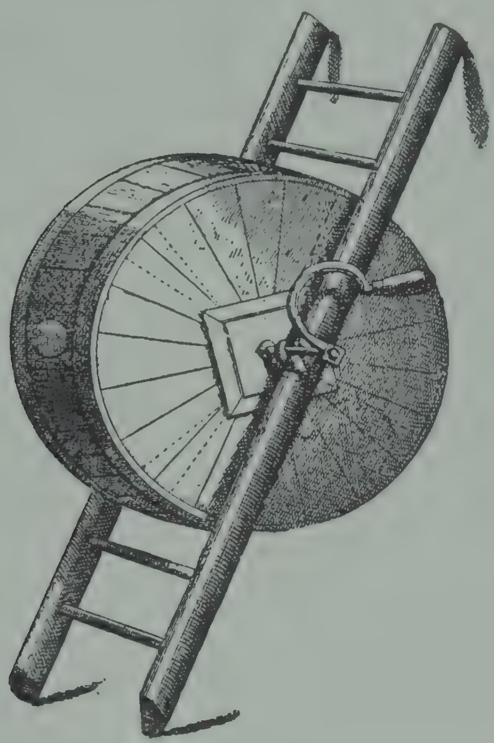


Fig. 6. Churn used in the Alpine huts of Switzerland

79 A. D.) refers in several instances to butyrum (butter) as an addition to bread.

Concerning the early history of the uses of butter, Hayward[5] reports the following:

"In the early times butter was employed in many ways. The Hindoos used it for the greatest and holiest sacrifices in their worship." It appears, however, that this custom, characteristic of the Hindoos, did not follow the invasion of butter westward, and it is noteworthy that the poets of Ancient Greece, such as Homer (about 850 B. C.), Euripides (480-406 B. C.), Aristoteles (384-322 B. C.), and others, never mentioned butter, while they repeatedly referred to milk and cheese.

"The Romans also used it as an ointment to enrich the skin and as a dressing for the hair. In the time of Alexander I. certain of the Macedonians anointed themselves with milk oil; and Galen records that in many cold regions people used butter in the bath. Historians speak of butter used as a remedy for wounded elephants, and within a century butter was used in large quantities in Scotland and North England for smearing sheep, also as oil for lamps. Besides being applied externally, it was used internally for various troubles. In Spain, as late as the 17th century, butter was to be found in the medicine

shops for external use only. In the middle of the previous century 'A medicinal and economic treatment of butter' sets forth in detail the value and use of butter as a remedy. In rural districts in Germany at the present time fresh, unsalted butter is much used as a cooling salve for burns.

"Aside from its use as a food, a cosmetic, and a medicine, the use or possession of butter was long regarded as indicating wealth, and so served to distinguish the rich from the common people. Evidences of this still exist. In both Chilas and Darel a practice exists of storing up butter in the ground. Butter so stored is left a number of years, and, to insure its not being disturbed, a tree may be planted over it. Under these conditions it turns deep red and is highly prized. The owner's wealth is computed by the quantity of butter he has stored up in this manner.

"Butter was enjoyed as a food by comparatively few people in its early history; those who did so use it seldom ate it fresh. The general practice was to melt it before storing away, and instead of being a spread, it was employed to enrich cooked foods. Others, even in comparatively recent times, used the rancid stored butter as an appetizer. In Dardistan peasants are said to highly value salted butter grease that has been kept a long time, and that which is over one hundred years of age is greatly prized.

"Little is known of the part which butter played as an article of commerce in ancient times. However, an early historian states that in the first centuries butter was shipped from India to ports of the Red Sea. In the 12th century Scandinavian butter was an article of over-sea commerce. The Germans sent ships to Bergen, in Norway, and exchanged their cargoes of wine for butter and dried fish. It is interesting to note that the Scandinavian king considered this practice injurious to his people, and in 1186 compelled the Germans to withdraw their trade. Toward the end of the 13th century, among the enumerated wares of commerce, imported from thirty-four countries into Belgium, Norway was the only one which included butter. In the 14th century butter formed an article of export from Sweden. It may be fairly inferred that buttermaking in north and middle Europe, if not indeed in all Europe, was introduced from Scandinavia.

"John Houghton, an Englishman, writing on dairying in

1695, speaks of the Irish as rotting their butter by burying it in bogs. His report was confirmed by the discovery, in 1817 and later, of butter thus buried, packed in firkins. This burying of butter in the peat bogs of Ireland may have been for the purpose of storing against a time of need, to hide it from invaders, or to ripen it for the purpose of developing flavor in a manner similar to cheese ripening."

According to Arup[6] one deposit of butter buried in peat bogs was found wrapped in a skin in Co. Leitrim, and another packed in a tub with perforated wooden handles (see illustration) in Co. Tyrone, Ireland. White[7] (1856) quotes from Butler's Hudebras:

> "Butter to eat with their hog
> Was seven years burried in a bog."

The archeology of bog butter is also dealt with in a communication to the Irish Times by Mr. Gogan[8], stating that a sample of buried butter was found in Tirnakill Bog, Co. Gallway, contained in a vessel dated 1789. It is believed probable that the practice of burying butter ceased in Ireland about the end of the 18th century and that many of the specimen which have been found, are of far greater antiquity (11th to 14th century), the age of the older specimen being approximately determined by the pyrographic decorations on the containing vessels, and in certain cases the age could also be deduced from the depth at which the specimen was found. The large number of specimen found. some of which weighed over 100 lbs., suggests that the burying of butter must have been a widespread practice in

Fig. 7. Keg of Bog-Butter found at Skye. Scotland
(From Hansen's Dairy Bulletin, Aug., 1933)

Ireland. Similar deposits of buried butter were also discovered in Iceland and in Finland.

Arup found this bog butter of a very rancid odor. It is probable that the many difficulties of storage and distribution of foodstuffs in former times, must have resulted in a considerable tolerance of rancid and highly flavored foods. There is evidence that a taste was developed for rancidity in butter. The Romans are said to have kept their butter until a certain degree of rancidity was produced.

The fundamental principle of churning and of the equipment used, likewise is traceable to the earliest times of which records relating to butter are available. Thus, the ancient Hindoos made their butter in the stationary type of churn based on the principle of the modern dash churn. They placed the liquid in earthen vessels and gave it a querling motion, either by beating it with their hands, or by stirring it with a stick terminating at its lower end in a butt or other primitive contrivance. These were the prototypes of our dash churn, in which the dasher terminates in a cross, or in a perforated round board or perforated tin cone fitting closely into the vertical churn; or of the diverse types of horizontal or vertical dash churns with revolving dasher.

The other principle of churn, i.e., the churn without internal agitator and in the operation of which the motion of the churn drum provides the churning agitation, such as is the case with the rolling, swinging, tumbling, or revolving churn of today, finds its prototype in the much cruder churns of the ancient Arabs, who used animal pelts sewed up to hold the milk. These pelts were manipulated by swinging and kneading until the butter formed.

Later Development of the Butter Industry.—The evolution of the art of butter making has been intimately associated with the development of equipment provided and used. From the early days of ancient history, to past the centuries of the Middle Ages the making of butter increased gradually, it spread to more countries and its importance gained growing recognition in government decrees dealing with the products of the farm. During the 12th century Scandinavian butter had become an important item of export. The archives of records for agriculture and livestock of those periods, however, fail to reveal

the occurrence of fundamental improvements in equipment and methods available for butter making. Primitive implements and the absence of the helping hand of science, therefore, precluded more rapid strides in the development of this now great industry.

With the close of the 18th century and the beginning of the 19th century, the construction and use of creaming and buttermaking equipment, other than that made of wood, began to receive consideration and the barrel churn made its appearance. By the middle of the 19th century constructive attention was given, both in this country and abroad, to improvement in the methods of creaming. These efforts gave birth to the Deep-Setting System. Up to that time the creaming was done according to the principle of the "Shallow Pan" system. The Deep-Setting system shortened the time of creaming, made possible more exhaustive skimming and yielded cream of better quality. In this country, this system of creaming was introduced in the State of New York shortly after 1850. Its further improvement yielded the Cooley System, in 1876, which found wide application in the United States, as well as in some sections of Europe.

Up to and including the middle of the 19th century the factory system of butter manufacture was practically unknown. The butter was made on the farm. The bulk of the butter was made during the summer months, at the time of surplus and low market price. In the absence of pasteurization and of knowledge of the factors that control keeping quality, and because of lack of adequate facilities for refrigeration, this butter yielded readily to flavor deterioration with age, so that accumulations of butter in the country stores at the end of the season usually showed poor quality, and this aged butter had the general character of the product now known as packing stock.

Renovated Butter Made from Seasonal Accumulations of Packing Stock.—The seasonal accumulation of unsold farm butter in the country stores, which by the end of the flush season had usually deteriorated in quality to such an extent, that it was no longer marketable and had to be disposed of as packing stock at a heavy sacrifice in returns, soon led to efforts to treat and remake this butter into a salable product. These efforts attracted capital and led to the manufacture of renovated butter. The process of renovating butter, which began in 1885, consists

of melting the butter, clarifying and refining the butter oil to remove objectionable odors and flavors, mixing the oil with skim milk, milk or cream, sweet or sour, and regranulating the oil in cold water or ice water. In the United States renovated butter was defined and its manufacture regulated by Act of Congress approved May 9, 1902. Its volume of production increased rapidly, amounting to over 50,000,000 pounds per year during the first decade of the present century. With the increasing shift from farm-made butter to creamery butter, and with the improved methods gradually adopted in farm buttermaking, the annual accumulation of packing stock decreased rapidly and this in turn reduced the output of renovated butter to a negligible volume. In 1903 renovated butter was manufactured in 81 factories located in the United States. Today fewer than 5 such factories are in operation. The production of renovated butter by years is shown in Table 1.

Table 1. Annual Production of Renovated Butter in the United States.[1]

Year	Production Pounds	Year	Production Pounds	Year	Production Pounds
1902	No record	1915	39,056,180	1928	3,160,465
1903	54,658,790	1916	34,514,527	1929	3,040,895
1904	54,171,183	1917	27,507,982	1930	1,850,000[2]
1905	60,029,421	1918	19,270,933	1931	1,236,000[2]
1906	53,549,900	1919	17,358,718	1932	950,000[2]
1907	62,965,613	1920	9,735,214	1933	1,079,000[2]
1908	50,479,489	1921	6,099,110	1934	1,548,000[2]
1909	47,345,361	1922	5,355,816	1935	2,016,000[2]
1910	47,433,575	1923	4,003,307	1936	2,456,000[2]
1911	39,292,591	1924	4,044,476	1937	2,715,000[2]
1912	46,387,398	1925	3,824,929		
1913	38,354,762	1926	2,482,660		
1914	32,470,030	1927	4,272,033		

[1]From A Handbook of Dairy Statistics by T. R. Pirtle, U. S. Dept. Agr., 1933.
[2]Agricultural Statistics 1939, U. S. Dept. Agr.

Beginning of Factory System of Butter Manufacture.—In the year 1870, which appears to be the last year before the introduction of factory butter making, the butter production in the United States was 514,092,683 lbs. This butter was practically all farm-made butter.

From that time on the manner, and especially the business of making butter underwent marked changes, gradual at first, and more rapid as the advantages of volume production became

more and more appreciated. The trend toward the making of butter on a larger scale suggested the urgent need of more suitable equipment and improved methods, the introduction of which, in turn, gave added impetus to the change from farm buttermaking to factory production.

Authentic records concerning the beginning of factory buttermaking are meager. It appears that the first butter factory was built by one Stewart in Manchester, Iowa, in the year 1871. The beginning of factory buttermaking also introduced the "pooling system" of creamery operation. This became popular especially in certain sections of the Middlewest. In this system numerous farmers took their milk to a small creamery, where it was set for creaming by gravity, either by the shallow-pan system, whereby the milk was placed into large shallow tanks or vats, or by the deep-setting system. In the latter case the milk was set in shipping cans, or other deep containers, which

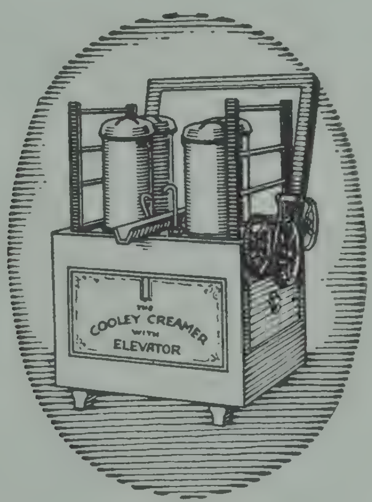


Fig. 8. The Cooley Creamer for Deep-Setting
Courtesy of De Laval Separator Co.

were then placed in cold water, and on the following day the cream was skimmed off by the operator and made into butter. The returns from the butter, after deducting the cost of making, were divided among the farmers on the basis of the pounds of milk delivered.

Thus the initial change from farm buttermaking to creamery butter manufacture established the whole milk creamery. But almost simultaneously with this system, the gathered-cream system also developed and became popular. The farmers again skimmed their milk on the farm, usually by the use of shallow pans, but later by placing the milk in deep-setting cans, set in water, and the cream was gathered by cream haulers.

Influence of the Centrifugal Cream Separator.—It was the inventive genius of the Bavarian brewer, Antonin Prandtl, in

1864, that conceived the idea of adapting the principle of the laboratory centrifuge used by the German chemist, C. J. Fuchs, in 1859, for determining the amount of cream in milk, to the centrifugal separation of milk. In 1877 the German civil engineer, Wilhelm Lefeldt, succeeded in designing a machine that, while as yet very primitive, was usable. These first efforts had to do with bucket centrifuges which were capable only of intermittent or batch operation, i.e., the separator had to be stopped and the containers emptied when the separation of the amount of milk which the machine was capable of holding was completed. Even in the early types of bowl separators the cream only, was removed continuously, while the machine had to be stopped for the removal of the skim milk. According to Fleischmann's[9] exhaustive review of the history of the centrifugal cream separator, it was not until the year 1879 that engineers in Sweden, Denmark and Germany succeeded in the construction of cream separators for fully continuous operation. The

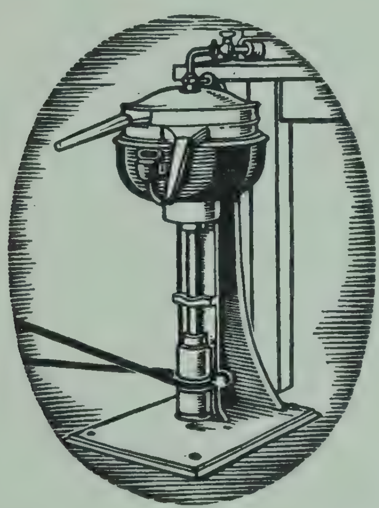


Fig. 9. The first commercially successful continuous discharge centrifugal cream separator
Courtesy of De Laval Separator Co.

first one of these machines known to have been used in Germany was one designed by the Swedish engineer, Dr. Gustav Patrik De Laval. This machine was imported into Germany and used in the creamery in Hamm near Hamburg in March 1879. Fleischmann further states that the De Laval Separators, excelled all other centrifuges in simplicity of arrangement and operation and in absence of sensitiveness to disturbances in operation. In 1886 De Laval invented the steam turbine which he immediately adapted to the cream separator, thereby vastly simplifying its mechanical operation.

The centrifugal cream separator was first introduced in this country during the years 1885 to 1890, and thereafter the invention and construction of American-made machines fol-

lowed in rapid succession. Simultaneously the creameries began to install the factory separator, and gravity creaming on the farm, especially in the more highly developed dairy sections, fell into disfavor. Gravity creaming was gradually abandoned, and the gathered-cream system again changed to the whole milk creamery system, the farmers hauling their milk to the creamery, where it was separated by power centrifuges, and the skim milk was returned to the farm. That was the "golden age" of the whole milk creamery system. The fresh, factory-separated cream yielded a great improvement in the quality of the butter. The creameries increased in number and in volume of butter made, and the annual production of butter in the United States increased rapidly.

Many creameries, in order to draw their milk supply from a larger radius of territory, established skimming stations, to which the farmers within hauling distance brought their milk. Here the milk was separated, the cream hauled or shipped to the central creamery and the skim milk was returned to the farm. Being built and equipped solely for the separation of milk, the initial investment was small and the cost of operation of these skimming stations was relatively low.

The whole milk creamery system flourished during the last decade of the 19th century and in the sections of intensified dairying it continued to grow well into the first decade of the present century.

In the early nineties of the 19th century, the development and perfection of the centrifugal separator had reached the stage where it could be adapted to practical use on the farm. De Laval was the first to manufacture hand separators for farm use. The first centrifugal hand separator was placed on the market in the year 1886. Its introduction on the farm, however, was slow. It began to gain momentum only after the beginning of this century, and then largely only in the sections of the Middle West where the herds were small and the milking of cows was but a side line of wheat farming or of general farming. Between the years 1905 and 1920, however, the hand separator grew rapidly in popularity, not only in the corn and hog states, but also in the more highly developed dairy sections. The succeeding decade (1920-1930) marked the adoption of the farm separator on practically every farm within the dairy belt of this country, where milk was produced for buttermaking purposes, to the

exclusion, with but few isolated exceptions, of the whole milk creamery.

With the adoption of the hand separator, the creameries again abandoned the whole milk system and returned for the third time to the gathered-cream system of factory operation. The development of this system during the first three decades of the present century was vastly expedited by the organization and activities of large centralized creameries, which established tens of thousands of shipping points, of cream buying stations, and of cream routes throughout the vast cream-producing territories. It brought into being also the independent cream buyer and the co-operative cream marketing association.

Advantages and Disadvantages of the Gathered-Cream System.—The hand separator and the gathered-cream system of butter manufacture thus have enabled the farmer, with but a few cows and located in territory where the cow population was too sparse to justify the establishment of local creameries, to find a ready market for his cream by shipping to a distant creamery. It has been the means of supplying the farmer's family with much needed, ready cash. It has increased the number of milch cows per farm and it has encouraged more farmers to milk cows. It has opened vast new regions to the profitable husbandry of the dairy cow, increasing the volume of creamery butter produced in the United States to over one and one-half billion pounds per year.

But, similar as in the case of other great strides forward, so has the hand separator brought in its wake, certain disadvantages and abuses that caused its benefits to fall short of their promised goal.

The much extended radius of the cream supply, and the fact that the bulk of the cream reached the creamery through one type or another of carrier or middleman, destroyed that close and direct contact between creamery and patron that existed in the days of the whole milk creamery, when each creamery had its fairly well defined and relatively close-by milk territory and the farmers themselves delivered their milk to the factory daily. Loss of this contact automatically diminished the sense of responsibility on the part of the patron toward the creamery, and the growing competition for volume, has tended to obliterate the local boundaries of the cream supply territory between

creameries. This in turn has curtailed the dependability of the daily cream supply, has increased the turnover of creamery patrons and has greatly augmented the difficulty and the cost of securing and holding patrons. The growing competition among the rapidly increasing number of creameries, for the farmer's cream, and improved transportation facilities, have brought about an uneconomical overlapping of agencies and carriers bidding for the gathering of the available cream, decreasing the volume per carrier and increasing the cost of getting the cream to the creamery.

The increasingly "floating" status of the cream supply, the loss of direct daily contact between creamery and patron, and the more and more keen competition among creameries for volume of raw material, had the inevitable effect of destroying the creamery's control over the quality of its cream supply. The patron relaxed in his vigilance in the production and care of cream. Less attention was paid to cleanliness and to the sanitary condition of separator bowl, milk utensils and cream shipping cans, to prompt and proper cooling, and to frequency of shipment or delivery of the cream. This in turn has caused much of the cream to arrive at the creamery in seriously deteriorated condition, especially during the hot summer months, lowering the quality of American butter. Unfortunately, efforts at cream improvement in many sections have been nullified by the unwillingness of competing creameries to pay for cream on the basis of quality.

While honest movements in the direction of cream of better quality, supported by State and Federal agencies, have not been lacking, yet the experience of the past suggests that, under the conditions existing in many regions of the United States at least, the only lasting solution of the poor cream problem, lies in a return of the whole milk creamery system. The desirability of such a movement is further accentuated by the growing economic necessity of larger returns from the sale of the product of the dairy cow, calling for the profitable utilization and the conversion into marketable manufactured products, of every solid ingredient contained in milk, in its by-products and its waste products. There are unmistakable signs that this trend away from farm-skimmed, gathered cream and toward the return to the whole milk system of creamery operation, has already started. This transition is further encouraged and facilitated by

present-day transportation facilities that make possible the daily delivery of milk produced within a comparatively wide radius, in the farmer's own automobile.

Influence of the Babcock Test.—With the beginning of the factory system of buttermaking, the urgent need of a method to determine the per cent of fat in milk and cream became more and more apparent, in order to enable the factory to pay the farmer on the basis of the butter fat value of his milk or cream. While the chemist was able to accurately estimate the butter fat by the ether-fat extraction method, this means was too difficult of operation and too slow of results for use in the creamery. The **creamometer** or **cream gauge,** in which the layer of cream rising on top of the milk was measured, the **churn test,** in which samples of cream from the individual farmers were churned in order to determine the amount of butter that the respective cream would make, and the **oil test,** in which the butter fat in samples of cream was melted out and measured, were successive steps in the earlier attempts to determine the correct market value of the farmers' milk and cream. While they were distinct improvements over the mere weighing and measuring of the cream received, they were slow of operation and often misleading in results, and, therefore, failed to serve as satisfactory methods. Several more or less practical methods devised in Europe did not prove applicable under the American creamery system.

Between the years 1885 and 1890 chemists at the several American Agricultural Experiment Stations, located within the dairy belt, bent their efforts on devising a method that could be readily used for the rapid and accurate determination of fat in milk and cream. These efforts brought forth several fat tests applicable for the purpose, but the test invented in 1890 by Dr. S. M. Babcock, Chemist at the Wisconsin Agricultural Experiment Station, now known as the Babcock test, is the only method which was adopted for general use in this country. In Europe Dr. N. Gerber, of Switzerland, devised a somewhat similar test, the Gerber test, shortly after the introduction of the Babcock test. The Gerber test has never come into general use in this country, but has found wide application in European countries.

The introduction of the Babcock test in American creamer-

ies proved of incalculable value to our butter industry, as well as to the dairy industry in general. It made it possible for the creamery to pay the farmer on the basis of the true butter fat value of his milk and cream. It enabled the producer to test the milk of his own cows, and thus gave him a practical means of determining the butter fat production of the individual cows in his herd. It assisted the food authorities in protecting the consumer against adulterated milk. Dr. Babcock has, therefore, been instrumental in placing the dairy industry of this country on a more substantial and permanent basis than it occupied prior to the introduction of the Babcock test.

Other leading dairy countries that have adopted the Babcock test as the basis upon which milk and cream are paid for are: Canada, Australia, New Zealand and the Union of South Africa.

Other Inventions Assisting the Development of the Butter Industry.—The closing years of the nineteenth century and the beginning of this century have witnessed numerous additional inventions and improvements of creamery equipment and methods, which have been of great service to the butter manufacturer.

Among the more important of these are the introduction of pasteurization and of the use of pure cultures of lactic acid and flavor bacteria, first advocated by Storch of Copenhagen, Denmark, and by Weigmann of Kiel, Germany, in 1887; the American invention of combined churns and workers, such as the Disbrow and Simplex in the early nineties, and later the Victor and Perfection and modifications thereof; the invention of artificial refrigeration and improvement of efficient refrigerator service on transportation lines; the rapid development of steam roads and electric interurban lines and the advent of the auto-truck and road improvement.

Cream ripening by the use of pure cultures of selected bacteria was accepted and taken up rapidly by American creamerymen, while pasteurization of cream for buttermaking was received with considerable reluctance and has become fairly general only within the last score of years. Today the great bulk of creamery butter is made from pasteurized cream and in some states legislation has been enacted requiring the pasteurization of all cream used for buttermaking.

Influence of Dairy Research, Dairy Instruction and Dairy Control.—In the development of the butter industry and of dairying in general the Federal and State Agricultural Experiment Stations, the dairy schools and other educational forces, and the law-making and enforcing agencies, must be considered as large factors. Much valuable experimental data has been produced in this country and abroad which has greatly assisted the creamerymen in improving their methods, in abandoning faulty processes, in reducing the cost of manufacture, in guarding against costly butter defects, and in raising the standard of excellence of the product.

The dairy schools have placed in the field hundreds of trained men annually, whose influence has worked for substantial and permanent improvement of the manufacturing processes. The extension work done by state and federal governments and commercial concerns has been of special service in assisting the producer of cream to produce more economically, to stimulate larger production, and to improve the quality of the raw material.

The organization and activities of local, state, national and international dairy and creamerymen's associations, unions and federations have been important agencies in promoting dairy interest, enthusiasm, and progress. These institutions have been instrumental in the formulation and passage of laws for the protection and constructive development of the dairy industry. They have helped in combating disease among dairy stock. They have provided means for prohibiting unsound practices, such as fraudulent testing of milk and cream. Their efforts have resulted in the control of the activities of the unscrupulous creamery promoter and in preventing the adulteration of dairy products. They have regulated transportation rates of milk and cream, and the sale of butter substitutes. They have been important factors in assisting in the establishment and enforcement of dairy standards and laws. They have stimulated the consumption of butter and other dairy products by organized campaigns for the purpose of acquainting the consuming public with the great food value, unexcelled wholesomeness and true economy of these products as articles of the human diet.

The dissemination of the wealth of scientific data developed by experiment stations and dairy research laboratories, has been vastly expedited by an active dairy press, whose current trade

papers and scientific journals have made this valuable information readily available to the busy man in the factory and to the industry in general.

All of these varied agencies of investigation, education, dissemination and control which, through liberal state and national subsidies, and through active and generous support by commercial institutions and public spirited individuals, have multiplied speedily during the last 50 years, both in numbers and activity. They have served as an additional and mighty impetus in the substantial and rapid development, and the permanent prosperity of the butter industry.

In countries with a butter output far in excess of domestic needs, necessitating the exportation of a large part of their annual butter production, the inspection and grading of cream

Table 2. Annual Production of Butter in the United States*

Year	Factory-made Butter[1] Pounds	Farm-made Butter Pounds	Total Butter Pounds
1849	None	313,345,306	313,345,306
1859	None	459,681,372	459,681,372
1869	None	514,092,683	514,092,683
1879	29,421,784	777,250,287	806,672,671
1889	181,284,916	1,024,223,468	1,205,508,384
1899	420,954,016	1,071,626,056	1,492,580,072
1909	627,145,865	994,650,610	1,621,796,475
1914	786,003,489	851,158,000	1,637,161,489
1918	822,718,916	710,000,000	1,532,718,916
1920	866,732,000	694,803,000	1,561,535,000
1921	1,057,114,000	681,803,000	1,738,917,000
1922	1,155,806,000	668,803,000	1,824,609,000
1923	1,244,118,000	655,803,000	1,899,921,000
1924	1,357,745,000	642,803,000	2,000,548,000
1925	1,363,300,000	629,803,000	1,993,103,000
1926	1,454,638,000	607,877,000	2,062,515,000
1927	1,497,712,000	585,952,000	2,083,664,000
1928	1,488,146,000	564,026,000	2,052,172,000
1929	1,598,248,000	542,064,000	2,140,312,000
1930	1,597,846,000	518,300,000	2,116,146,000
1931	1,667,452,000	529,320,000	2,196,772,000
1932	1,694,132,000	566,200,000	2,260,332,000
1933	1,762,688,000[2]	534,143,000	2,296,831,000
1934	1,694,708,000[2]	558,649,000	2,253,357,000
1935	1,632,380,000[2]	551,520,000	2,183,900,000
1936	1,629,407,000[2]	522,980,000	2,152,387,000
1937	1,623,971,000	508,340,000	2,154,000,000
1938[3]	1,786,172,000	500,055,000	2,286,227,000
1939[3]	1,757,395,000	500,000,000	2,257,395,000

*Pirtle, T. R.: A Handbook of Dairy Statistics, 1933.
[1]Includes Whey Butter.
[2]U. S. Dept. of Agr. Year Book, 1938.
[3]Preliminary

and butter under government control, has been an important factor in the constructive development of the creamery business through compulsory improvement in quality. This is especially true of such butter exporting countries as Denmark, Canada, New Zealand, Australia and the Union of South Africa.

ANNUAL BUTTER PRODUCTION

The annual production of butter in the United States by years is shown in Table 2. In the year 1936 it amounted to 1,629,407,000 lbs. of creamery butter, of which a little over 41% was made in the States of Iowa, Minnesota and Wisconsin. The total butter production of the world is approximately 7¼ billion pounds. Including the 504,620,000 lbs. of farm butter, the total butter produced in the United States in 1937 amounted to approximately 30 per cent of the estimated total butter production in the world's principal dairy countries, which are listed in Table 3.

Table 3. Annual Production of Butter in the Leading Butter Producing Countries of the World*

Country	Year	Total Production Pounds	Country	Year	Total Production Pounds
United States	1937	2,154,000,000	United Kingdom	1937	96,000,000
Germany	1937	1,140,000,000	Argentine	1936	70,000,000
France	1936	564,000,000	Finland	1936	61,000,000
U. S. S. R.**	1936	414,000,000	Switzerland	1937	58,000,000
New Zealand	1936–37	404,000,000	Brazil	1936	55,000,000
Denmark	1937	403,000,000	Latvia	1936	49,000,000
Australia	1936–37	375,000,000	Union of So. Africa	1935	47,000,000
Canada	1937	360,000,000	Lituania	1937	38,000,000
Netherlands	1937	222,000,000	Egypt	1935	36,000,000
Eire	1935	183,000,000	Czechoslovakia	1936	30,000,000
Sweden	1937	161,000,000	Estonia	1936	30,000,000
Belgium	1937	139,000,000	Norway	1937	27,000,000
Italy	1934	99,000,000			
			Total Butter Production		7,215,000,000

*From New Zealand Official Yearbook, 1939.
**Estimated.

Table 4 offers a general picture of the proportionate utilization of the annual production of milk in the United States for manufacture of dairy products. These figures show that 56.06 per cent of the entire annual milk production is utilized in the manufacture of dairy products, of which 42.28 per cent

is disposed of in the form of butter and 13.79 per cent is manufactured into dairy products other than butter.

Table 4. Proportion of Milk Produced in U. S. A. in 1936 Used for Butter and for Other Dairy Products*

Product	Milk Used Per Unit Product Pounds	Quantity of Product Manufactured Pounds	Whole Milk Used Pounds	Percentage of Total Milk
Milk produced by cows on farms			103,183,000,000	....
Milk produced by cows not on farms			2,826,000,000	....
Total Milk produced			106,009,000,000	
Creamery butter	21.	1,629,407,000	34,217,547,000	32.27
Farm butter	21.	504,620,000	10,597,000,000	10.00
Cheese (all kinds)	10.	642,551,000	6,425,510,000	6.06
Evaporated whole milk	2.	2,043,759,000	4,087,518,000	3.85
Condensed whole milk	2.5	226,580,000	566,450,000	0.53
Dry whole milk	8.	18,180,000	145,440,000	0.14
Dry cream	19.	178,000	3,382,000	
Malted Milk	2.2	18,495,000	40,689,000	0.04
Ice cream (gallons[1])	13.75	243,551,000	3,348,826,250	3.16
Total milk used for all manufactured products			59,432,362,250	56.06
Milk used for butter manufacture			44,814,547,000	42.28
Milk used for manufacture of products other than butter			14,617,815,250	13.79
Whole milk fed to calves			2,794,000,000	2.63
Whole milk used for fresh consumption and for miscellaneous unspecified purposes			43,782,637,750	41.30
Total milk used for all purposes			106,009,000,000	100.00

*Calculations made on basis of volume of manufactured products and of total milk production quoted in U. S. Dept. Agr. Year Book 1938.
[1]Refers to production in commercial ice cream factories only.

REFERENCES

1. HUMBOLDT, A. VON., Kosmos, Stuttgart u. Tübingen (Cotta) II, 488, (1847).
2. MARTINY, BENNO A. H., Die Milch, ihr Wesen u. ihre Verwertung, I, 6, (1871).
3. MARTINY, BENNO A. H., Kirne und Girbe, Berlin, (1895).
4. HAAS, quoted by MARTINY (2).
5. HAYWARD, H., U. S. Dept. Agri., B. A. I. Circ. 56, (1904).
6. ARUP, P. S., Analyst, LVII, 674, (1932).
7. WHITE, W. R., Proc. Royal Irish Acad. *6*, 356, (1856).
8. GOGAN, Irish Times, May 16, (1929).
9. FLEISCHMANN, W., Lehrbuch der Milchwirtschaft, (1915).

CHAPTER II

CREAMERY ORGANIZATION, LOCATION, AND CONSTRUCTION

CREAMERY ORGANIZATIONS

From the standpoint of ownership and control there are principally four different types of creamery organizations; namely, the mutual co-operative creamery, the joint stock company with co-operative features, the proprietary factory, and the creamery corporation.

The Mutual Co-operative Creamery Association.—This is strictly a farmers' co-operative association. Its purpose is to pool the milk or cream of the individual members, the farmers, to manufacture it into butter and to sell the product, by the employment of a buttermaker, and manager and in this manner to save equipment and labor needed for manufacture and sale of the product, to secure greater skill for manufacture, to make a better product, and to sell it to better advantage.

In the truly mutual co-operative creamery association, every stock holder must be a milk or cream producer; he must be a patron of the creamery, but not every patron need be a stock holder.

The amount of money needed and decided upon for building and equipment, usually governs the amount of the capital stock to be issued. The shares of stock usually range from $10.00 to $100.00 per share. As it is desirable to have as many patrons as possible that are also stock holders and who are, therefore, interested financially in the creamery, shares of small denominations have their advantage.

The creamery may pay the farmers in the form of a nominal dividend, according to the number of shares of stock held, as stipulated by the articles of incorporation. The net returns from the business, which consist of what is left after deducting from the remaining gross receipts accruing from the sale of butter and other products, all expenses of operation and overhead, such as labor, supplies, fuel, water, power, refrigeration, package, sales expense, administration, interest, taxes and insurance, and after deducting a fixed amount placed in a sinking

fund for depreciation, repairs and replacements, may then be prorated among all patrons on the basis of the pounds of butter fat each patron delivered.

Or, the Board of Directors may pay for the milk and cream on the basis of current market quotations for butter, and after deducting the milk and cream checks and all other expenses above enumerated, from the gross receipts of the business, the balance of net returns, if any, may then be prorated to all patrons on the basis of the amount of butter fat delivered by each patron.

The mutual co-operative association may operate entirely independently as to sales, maintaining full control over all of its sales, including both local sales and sales in the larger central markets, or it may have affiliation with a central co-operative selling agency which handles all sales with the exception of the creamery's local sales.

The mutual co-operative creamery association has been a very successful institution, in localities where the cow population is dense and where the farmers are imbued with the co-operative spirit. It has stimulated milk production by making it more profitable. The co-operative service of the association has often extended its useful offices beyond the making and selling of butter and its by-products, to the co-operative buying of feed, fertilizers, farm supplies and machinery. It has stimulated community interest and general rural uplift.

Outstanding examples of butter-producing countries in which the mutual co-operative creamery association type of creamery predominates and has proven eminently successful are Denmark, Finland, Holland, Sweden, Switzerland, New Zealand, Australia, and parts of the states of Iowa, Minnesota, Wisconsin, and the Pacific Coast States. This form of creamery is not so well suited, however, in localities where the co-operative spirit is lacking and where the dairy herds are small, few and far between.

The Joint Stock Company with Co-operative Features.— Many, if not most of the so-called co-operative creameries are not purely mutual co-operative creamery associations, but they are joint stock companies with some co-operative features. To this type of creamery companies also belong the promoters' creameries. The joint stock company with co-operative features

differs from the mutual co-operative association largely on the following points:

1. A stock holder need not be a patron of the creamery.
2. The capital stock is divided into equal shares.
3. The members of the association usually cast one vote for each share of stock held.

While it is usually intended to have the patrons own the majority of the creamery's stock, so as to have as large a number of active patrons financially interested in the enterprise as possible, and thereby encourage permanency of the milk and cream supply, the results of organization not infrequently fall short of these ideals. In many instances a large portion of the company's shares of stock are held by townspeople and others who do not keep cows, limitating the much needed volume of raw material and rendering profitable operation difficult, if not impossible. It has constituted one of the weak links in the fabric of the promoter's creamery, the establishment of which often occurred in localities which lacked the fundamentals of successful creamery operation—sufficient cows, and farmers embued with the spirit of co-operation.

From the standpoint of control of sales the situation is similar as in the case of the mutual co-operative creamery association. Some of the joint stock companies with co-operative features handle their sales independently, maintaining full control over local sales and sales in the larger and more distant sales centers. Others are affiliated with a central sales agency which manages all sales except the local sales, but which has otherwise little, if any control over the association's internal operations or policies.

The fitness of a locality for the successful operation of a joint stock company with co-operative features, depends on conditions similar to those of the mutual co-operative creamery association.

The Proprietary Creamery.—This form of creamery organization refers to an enterprise owned or operated, or both, by an individual or by several individuals who have formed a partnership. In this case the owner, or owners, usually buy the milk and cream outright at prices generally based on the market quotations that prevail in the locality where the creamery's butter is marketed.

The patrons' responsibility and interest in the enterprise is confined to the sale of their product to the creamery, and ceases with the delivery or shipment of the milk or cream and receipt of the creamery's payment for the same, on the basis of its own quotation.

The proprietary creamery usually handles all sales independently and without control by or affiliation with any central sales agency. In the case of partnership the profits and losses are shared according to the amount of money invested by each partner.

The proprietary creamery obviously does not depend on the co-operative spirit of the farming community. Its volume of milk and cream receipts is largely a matter of price offered and service rendered, of intensity of competition and of confidence on the part of the patron in the integrity of the creamery. It is in the business to make profit from the investment of capital, and its legitimate transactions are unhampered by association articles and by-laws.

Partnership creameries have the disadvantage of all partnership enterprises. Each partner of a firm is individually liable for all debts of the firm, contracted either with, or without his consent.

The proprietary creamery may be found in successful operation in practically every dairy country. It is especially predominant in Canada, where it outnumbers all other creamery organizations. It is also well represented in many sections of the United States, Germany, England and Ireland.

The Creamery Corporation.—The creamery corporation is a joint stock company without co-operative features. It differs from the proprietary creamery in that it is an incorporated organization, hence each stockholder is liable only to the extent of the amount of the money he invested. This limited liability feature of the joint stock company is attractive to investors and renders this type of creamery organization popular. Its relation to the milk and cream producer is similar to that of the proprietary creamery.

Its unlimited possibilities have attracted and invited men of business enterprise and of capital into the creamery business in all parts of the country, and especially in the great stock-raising and grain-growing sections of the middle west and far west, where the cow population is not dense enough for the

successful operation of local co-operative creameries.

Its operations usually extend over a wide area—state-wide or even nation-wide. In many instances, it does its manufacturing in branch plants whose internal organization, policies and operation are closely supervised by its main or central offices. The central offices also handle all sales in the larger markets. The branch plants, besides receiving milk and cream from direct deliveries, direct shippers, route haulers and independent buyers, depend for much of their volume of cream receipts on the establishment and operation of cream buying stations and concentration points, which are usually scattered over a vastly extended territory.

This type of creamery organization has lent itself admirably to the establishment and operation of large centralized creameries, who draw their supply of raw material from a vast area. It is furnishing a ready and profitable market for the dairy product of the general farmer who milks but a few cows, and with whom dairying is a side line rather than the main business. It has opened up new regions of the country to dairying and has made possible the husbandry of the dairy cow in sections where dairying was formerly thought unprofitable. It has been a potent factor in agricultural development, by increasing the country's annual volume of milk and butter produced, accelerating the restocking of the land, improving the fertility of the soil, and making farming more profitable.

The creamery corporation has probably reached its largest development in the great corn belt states, the middle west of the United States. It is also much in evidence in Canada, and it is found variously developed in most of the butter-producing countries.

In the United States it appears to have reached its zenith during the first and second decades of the present century, resulting in the increasing establishment of large factories. Toward the end of the third decade and from then on the general trend has been in the direction of decentralization and of diversification of products, favoring the return to smaller units of more local character.

CREAMERY LOCATION

Importance of Suitable Location.—When considering the suitability of a location for the establishment of a creamery,

it is essential to give consideration to every potential factor or condition that is related to and may affect the net returns of the prospective business.

Such consideration has for its background the fact that today the margin of possible profits from the manufacture of butter is so narrow that even slight differences in volume of production, in cost of transportation and of factory operation, and in natural facilities affecting quality, may readily mean the difference between success or failure of the creamery business.

The factors relating to location of the creamery, that compel particular attention are: source of milk and cream supply, access to butter markets, transportation facilities, volume and quality of water supply, availability and cost of fuel, power and labor.

Proximity to Milk and Cream Supply.—The auto-truck and other means of modern transportation have brought both, the source of the supply of raw material and the market for the finished product, closer to the door of the creamery. The problem of getting the supply to the factory has, therefore, been simplified, greatly increasing the radius of its available source. The greater volume of production thus made possible, assists in cutting down the cost of manufacture, offsetting partly, or wholly, or more than wholly, the higher procurement cost of long distance hauls.

Nevertheless, the cost of transportation, regardless of form of conveyance, is an important item in the gross expense of the creamery business, and since the shipping of butter fat in the form of milk and cream costs more than it does in the form of butter, the factor of cost of transportation alone suggests the advantage of locating the creamery as near the supply as possible. Closeness to supply of raw material also facilitates contact with the producer, thus making for maximum efficiency of service, such as prompt return of empty cans, prompt receipt of milk and cream checks, dissemination of helpful information on proper care of milk and cream, and on diverse phases of dairy farm management. Proximity to cream supply shortens the time during which the farmer's product is in transit, minimizing the danger of damaging deterioration.

Proximity to Markets.—Generally speaking, the local market is the most profitable market. It eliminates the cost of

transportation and reduces to the minimum sales overhead. It is advantageous for the small local creamery that is considering a location near the cream supply, to establish itself in a growing town of good size and with ready access to promising neighborhood markets. The output of the large centralized plant, on the other hand, calls for channels of distribution in the large consuming centers. Its most advantageous location usually is that of a central location in the cream supply territory, with favorable transportation arteries to the great consuming centers of the country.

Water Supply.—A plentiful supply of pure and preferably cold water is a necessity for successful butter manufacture. The water supply should be free from excessive contamination with organic matter, undesirable germ life, and objectionable mineral constituents, such as sulphur and sulphur compounds, iron and chlorine. Water that is biologically polluted is a constant menace to the quality of the butter and may cause disastrous epidemics of costly butter defects. Water containing abnormal quantities of objectionable minerals usually intensifies corrosion and shortens the life of the equipment, and it may seriously jeopardize quality. The availability of good, cold water is a valuable economic asset, as a means of lowering the cost of refrigeration.

Absence of objectionable hardness such as results from high content of sulphates, carbonates or silicates, is of added advantage. However, such hardness usually responds satisfactorily to treatment with suitable water softeners, that largely eliminate its principal objections for boiler and factory use. Mere hardness, therefore, need not condemn the water supply for creamery purposes, if the water is biologically pure and free from objectionable organic matter and damaging minerals.

For above reasons it is wisdom to make a careful survey of the available water supply of the community in which it is contemplated to locate a creamery, subjecting the water to examination and analysis, ascertaining volume and water rates, determining the possibilities of drilling wells and testing the water of wells already in operation in the vicinity, for purity and general suitability. For further details on treatment of hard waters, see also "Boiler Feed Water" in Chapter III, and "Washing Powders" in Chapter IV.

Sewage Disposal.—Facilities for the satisfactory disposal of the creamery wastes constitute an important problem in the consideration of the choice of a town for the creamery. Unless the location provides a sewage outlet to a creek or stream, with an ample flow of water throughout the year for adequate dilution, or there is dependable assurance of drainage rights to the municipal sewage system, the creamery may be compelled to resort to artificial methods for the disposal of its wastes. Because of the relatively high concentration of solids and the exacting character of wastes from milk products factories, the treatment of creamery sewage is usually associated with difficult problems. Numerous methods have been devised and tried, all of them involve considerable expense, both cost of initial installation and cost of operation, and few, if any, have proved entirely satisfactory. There is obvious wisdom, therefore, in ascertaining the sewage disposal facilities of the community considered for the establishment of the creamery.

Power, Steam and Refrigeration.—In the modern creamery the butter making equipment, such as forewarmers, vats, pasteurizers, churns, pumps, separators, can washers, well pumps, etc., are equipped with direct motor drive, doing away with steam engines and line shafts, and limiting the steam requirements to the steam needed for pasteurization, washing and sterilizing the equipment, and heating the building. Artificial refrigeration has taken the place of natural ice.

The electric power can usually be purchased at lower cost from a municipal or commercial plant than it can be produced within the creamery. Municipal and commercial steam and refrigerating establishments also often furnish a cheaper supply of steam and refrigeration than the creamery itself can produce.

When considering the location of the creamery it is wisdom, therefore, to consider the availability and cost of power, steam and refrigeration from municipal and commercial establishments, as compared with the cost of the available fuel supply such as sawdust, wood, coal, crude oil and natural or artificial gas.

Labor.—The cost of labor in creamery operation is a sufficiently important item to suggest the advisability of giving the labor situation of the locality in question serious consideration. Next to the cost of the raw material—milk and cream—and of

its procurement and delivery to the factory, the labor constitutes the largest item of cost in the creamery business.

The importance of a satisfactory source of labor here is augmented by the usually wide seasonal and often daily spread in volume of manufacture, that makes unavoidable changes in number of employees and in number of working hours, and therefore, demands unhampered freedom on the part of the management to make the necessary adjustments with the changing requirements. The labor situation, as well as the price and character of available labor, are generally more favorable in moderate size country communities than in large industrial centers.

Choice of Creamery Site.—Cities and towns generally have three classes of locations from which the site for the creamery may be selected, namely the wholesale district, the retail district and the residential district. Each has its advantages and disadvantages.

The Wholesale District usually provides proximity to railroad facilities, that minimizes cost of cartage between factory and rail, of outgoing finished products and of incoming raw material, supplies and fuel. It practically eliminates complaints of creamery odors, smoke and noise. On the other hand, its sanitary status may be more or less objectionable and may compel the creamery to provide for air purification. Its distance from the center of distribution precludes local advertising benefits and discourages counter sales at the plant.

The Retail District provides advertising benefits and offers exceptional opportunity for counter sales. Its usual distance from railways, however, tends to increase the cost of cartage and it generally lacks convenience for receiving milk and cream and for out-of-town distribution. In this district property is invariably expensive.

The Residential District has the advantages of pure air, and opportunity to obtain new customers at the plant. Its property is less expensive and there is less congestion of traffic. Its railway facilities, however, are poor, and the creamery odors, noise and smoke may condemn it as a nuisance. Even if a building permit is granted, operation may be seriously handicapped by restrictions and the passage of zoning laws may outlaw its future operation. At best the utilization of by-products in the

form of condensed or dried buttermilk would not be tolerated in the residential district because of unavoidable, objectionable odors.

Regardless of district, the site selected should provide clean surroundings and good drainage from plant to sewage system.

CREAMERY CONSTRUCTION

Profiting by the Latest Ideas and Experiences of Other Newly Constructed Plants.—It is not the purpose of this volume to provide plans and specifications of building and detailed instructions covering manner of construction. The size, type, architecture, internal arrangement and the materials used for construction must of necessity vary with such widely varying factors as size, dimensions and topography of the available lot, personal preferences and capital available for such use on the part of the prospective builder or owner, volume of expected business, number and type of products and by-products to be manufactured, and character of equipment to be installed.

In the face of this multitude of variables involved, it appears obvious that a detailed discussion of the innumerable items dealing with the construction of a suitable building would be of too limited value to the average reader to justify its appearance in this treatise. The present discussion, therefore, omits reference to details of construction such as are generally supplied by the professional architect and contractor. It confines itself largely to suggestions based on experiences and observations from the viewpoint of the creamery operator.

It is further recommended to those contemplating to erect a new factory, to visit other newly constructed plants. Such visits and the exchange of experiences with other operators thus made possible, are usually fruitful of contact with the latest ideas on modern construction, interior arrangement and type of equipment. Not infrequently plans and specifications of other plants may also be obtainable. These diverse sources of information help the prospective builder to profit by the experience of others and to incorporate in his new plant the best features of a number of modern factories.

Type of Building.—For small creameries, with an annual make of less than about 500,000 pounds of butter, a one story building may prove most suitable. For plants with larger make,

the arrangement of a one story building of suitable dimensions for most economical operation and adequate storage room to carry the needed stock of supplies generally is more difficult. A two story structure for creameries of over 500,000 pound annual make appears most suitable and most economical. In this case it is usually advantageous to devote the entire ground floor to manufacturing and power equipment, and to utilize the second floor for office, storage of supplies, buttermilk tanks, sweet-water tempering tank, brine tank and possibly ammonia condensing coils. In creameries of very large make, and where it is desired to establish the gravity system of arrangement and operation, it may be of advantage to use a separate story for each department of manufacture, starting at the top with the receiving, weighing, sampling, testing and "dumping" of milk and cream, and the washing of cans. The next floor below is then used for the separation of milk and the neutralization, pasteurization and cooling of cream, the next lower floor for holding the cooled cream, for cream ripening and for butter culture work, the floor below that for churning and butter coolers, and the basement for the power plant.

Size of Building.—While economy of operation dictates concentration of the necessary equipment in the minimum space required for convenient and efficient operation, so as to eliminate avoidable steps, handling and labor, there is wisdom in planning the building sufficiently large to allow for setting aside a reasonable amount of space not immediately needed. This will provide opportunity for much desired later expansion of new manufactured products and by-products, such as for instance, condensed or dried skim milk and buttermilk, casein, cottage cheese, etc.

Materials of Construction.—Generally speaking, the interests of the creamery are served best by the use of material that makes for substantial, durable and sanitary construction, that reduces the necessary cost of annual upkeep to the minimum, and that eliminates unnecessary extravagance. Show creameries, involving large investment, may become a stumbling block to profitable operation, nor do they necessarily symbolize high sanitary standard or superior quality of product.

Foundation and Outside Walls.—The footings, foundation and floors can prove satisfactory only when constructed of substantial non-rotting material. The material for the super-

structure is best chosen according to availability and financial ability. Most of the buildings with wood-frame construction are old buildings. Satisfactory materials for present-day creamery construction are brick, stone, reinforced concrete, concrete blocks, hollow tile with or without stucco finish.

Inside Walls and Ceiling.—The inside walls should be of smooth finish, that is durable, water- and steam-proof, and that is easily cleaned, such as is provided by glazed or enameled tile, enamel cement, cement plaster. Brick and concrete surfaces should be smoothly finished on the inside and protected with paint that will stand hot water or steam. In the case of wooden walls and partitions the concrete of the floor should extend at least two feet and preferably higher up the wall.

Ceilings may be constructed of similar material and finish as the inside walls. They are usually of matched lumber (varnished or painted), galvanized iron sheeting (painted), plaster and lath, or cement plaster. Even with the most efficient system of ventilation some condensation of moisture on the ceiling at times is unavoidable. The ceiling, therefore, should be constructed of, or finished and coated with material that is moisture-proof and acid-proof. The finish should be smooth, to facilitate washing and to not encourage mold development.

The Roof.—For economical construction the flat roof, with just enough slope to properly drain into the eaves, is most suitable. Steep gable roofs are expensive. Not only does their construction proper come relatively high, but they require much construction without providing added usable space. The space under the gable is lost space.

For a flat roof, such durable but expensive covering as tile or slate is suitable only in the warmer climes that are free from frost. In sections with cold winters the freezing and thawing is destructive to tile and slate, except in the case of steeply sloped roofs that carry off the water quickly. For serviceable and relatively inexpensive roofing, smooth-surface asbestos roofing, or tar and asbestos, using asbestos felt, or tar or pitch and gravel, are recommended. Ordinary tar paper, while cheap, lacks in durability. It is applicable only on reasonably steep-slope roofs.

It is usually advisable to contract for a 15 to 20 year guar-

antee-bonded roof, with a well established, reliable roofing house. The average local roofing concern may be and frequently is out of business long before the termination of the bond.

Floors.—All floors in the operating rooms are preferably constructed of concrete with cement surfacing, or similar durable, impervious material. The life of the cement floor depends to a large extent on its foundation. A durable cement floor must rest on a well-prepared, thoroughly tamped, solid foundation, covered with at least 3½ inches of good concrete below the cement surfacing. The application of a reliable concrete hardener will greatly help to make the cement more nearly wear-, water-, dust- and crack-proof. On the receiving floor, or platform, where the cream cans are handled, inlaid steel plates materially protect the floor against excessive wear. For a durable cement floor the following mixtures are recommended:

Concrete: 1 part cement, 2 parts coarse aggregate (clean gravel) and 3 parts clean sand, using as little water as possible —just enough to secure a satisfactory bond. Ordinarily, 4 to 5 gallons of water per sack of cement is sufficient. Excess water weakens the concrete.

Top Surfacing: 1 part cement, 8 parts of ¼″ to ⅜″ crushed sand or gravel and 1.2 parts of clean fine sand. Mix very thoroughly, using a small amount of water. Cast the topping, or wearing coat integral with the base concrete, trowel smooth, bring the surface level with the adjoining floor.

The new cement floor should not be used for at least one week. This will permit it to thoroughly harden. Hot water, especially, should be kept off the new cement floor for a period of at least 72 hours. Hot water is very detrimental to new concrete. Also keep the new concrete wet or moist for a period of 72 hours. This will prevent too rapid drying that would cause cracks or checks in the surface. These precautions mean much to the life and service of cement floors.

The cement should be carried up on the walls and partitions at least two inches or more, forming a sanitary cove. In the case of wooden walls and partitions, it is advisable to extend the concrete several feet up on the wall, or to lath and plaster the lower four or five feet.

The floors should slope not less than one-eighth inch per foot. The slope should be uniform and even throughout, and

low places should be avoided. Pipes or conduits should never be laid in or under the concrete floor. This refers to steam pipes, condensate return pipes, water pipes, brine pipes, ammonia liquor and expansion pipes, electric conduits, air ducts. The only pipes that belong under the floor are the sewer pipes.

Drainage and Drains.—All floors of the manufacturing rooms should slope downward toward the drains, so as to facilitate rapid and complete draining. Large, water-sealed floor drains should be sufficiently numerous and well placed in all rooms to rapidly carry off the water. The tops of these floor drains should be about one-half inch below the surface of the adjoining floor, so as to catch the water readily. This feature must be personally supervised by the creameryman, as the average contractor is prone to place the drain top level with or a trifle above the surrounding floor, expecting the water to flow "up hill."

An open drain ditch in the floor directly under or behind the churns will facilitate the rapid elimination of rinsings from churns and vats, that flood the floor. Usually a ditch about 8 to 12 inches wide, of suitable depth and proper slope, and with outlet to sewer, trapped by a large bell-trap or other equally efficiently, water-sealed trap, serves the purpose. If this ditch extends to parts of the floor where there is considerable traffic, it is best covered with heavy, perforated iron plates or iron grating. Or, in the place of the deep ditch, the floor may be dished out over a greater width and to a lesser depth. This arrangement usually proves more satisfactory than the ditch, as it will carry off the water with equal, if not greater ease, has no sharp concrete edges to chip off, can be kept in sanitary condition more easily, and eliminates the need of any covering.

The main drain pipe that leads out of the building should be of ample size. For creameries of small volume it should be not less than 6 inches in diameter, and 8 to 12 inches for creameries manufacturing over 500,000 pounds of butter annually. Where the creamery waste water is disposed of through the municipal sewer or goes to a dry well or seepage tank, a suitable grease trap with manhole cover should be provided.

The Grease Trap.—This is a small, tight cistern, usually made of concrete, through which all creamery waste must pass. It should be located immediately outside of the factory and be

readily accessible for cleaning. The purpose of the grease trap is to free the waste water as much as possible from the fat it contains, which causes the clogging of sewage filters. In order for the grease trap to properly serve its intended purpose, it should be constructed on the following principle:

Its intake from the factory should be near the top and its outlet to the sewer or other disposition, on the opposite side. Between these two openings a partition, approximately in the middle of the trap, is installed, which should extend to within about 6 inches above the bottom of the trap, and the top of the partition should reach above the level of the two openings which let the creamery waste in and out of the trap.

The incoming waste, therefore, is held back by the partition. It cannot flow across the surface of the grease trap and out through the exit. It must pass under the partition before it leaves the trap through the exit. The grease or fat, remaining on the surface of the liquid by reason of it being lighter than the remainder of the waste, therefore, stays on the intake side of the partition. It cannot reach the exit. Thus the grease trap serves as a grease separator and collector. For efficient functioning the grease trap should be cleaned out weekly.

Light.—A reasonable number of suitably distributed windows is desirable for satisfactory operation during daylight hours, without the help of artificial lighting. In one story plants the installation of skylights is advisable. With windows suitably hinged and equipped for convenient opening, the skylight provides also ventilating facilities. It has the additional advantage of attracting the flies to the ceiling and of keeping them away from equipment and product.

All windows should be efficiently screened and, excepting north wall windows, should be provided with suitable shades for facilitating control of the fly pest and for protecting the cream and butter against damaging oxidizing action of direct sunlight. (See also "Combating the Fly Pest," in Chapter V). A satisfactory distribution of ample electric lights is needed for operation at times and under conditions where natural light is either not available or not desired.

Ventilation.—The creamery needs adequate ventilation to afford ready and quick removal of free steam, to efficiently expel foul air, and to make possible satisfactory control of tem-

perature. Unless the mass of free steam that befogs the atmosphere in every creamery at times, finds a ready exit and is expelled from the factory quickly, it will condense and cause walls and ceilings to sweat and drip. This condition hastens the decay of walls and ceilings, shortens the life of motors, belts and other equipment, and encourages the appearance of mold on walls, ceilings and supplies.

Even in plants where the receiving, dumping and can washing department is separated by partition from the manufacturing room, much free steam is escaping from the washing and sterilizing of churns, vats, forewarmers and other buttermaking equipment and operations, and vapors laden with volatilized products arise from pasteurizers and surface coolers. The satisfactory expulsion of all of these vapors requires a positive, continuous and properly controlled movement of the factory air. Such ventilation is essential also for the removal of foul air and the control of temperature for the comfort, health and efficiency of the employees, and for the protection of the product against damaging contamination.

Experience has amply demonstrated that mere gravity ventilation provided by flues, such as the King system which is so successfully used in dairy barns, is entirely inadequate in the manufacturing rooms in the creamery. The circulation and exchange of air provided by gravity ventilation, depending exclusively on the temperature difference of the atmosphere between the inside and outside of the building, is too slow to remove the free steam from the creamery before it condenses on walls and ceilings.

In some installations, use is made of the creamery smoke stack to boost the expulsion of the steam-laden air. In this case an outer chimney is built around the smoke stack, with an air space between the two. Air ducts from the creamery lead into this air space, where the air strikes the hot smoke stack, intensifying the air current and expediting expulsion of the creamery air.

Under most conditions it has been found necessary, however, to resort to mechanically forced ventilation, hooding the equipment from which free steam escapes in large volume, such as can washers and steamers, forewarmers, pasteurizers, etc., and expelling the steam and air from the hoods through large air ducts to the outside by suction or blower fans. Ventilating

shafts terminating in a penthouse equipped with motor-driven fan are serviceable for this purpose, provided the fan motor is adequately protected from the steam and acids that escape, or that the motor is located outside of the penthouse.

For satisfactory functioning, the hoods should have steeply sloped sides and ends, at an angle of at least 45 degrees, to minimize friction and accelerate the upward movement of the steam. The bottom of the hood should terminate in a channel and drip, for collecting such condensation as may run down from the air flue. These hoods may be constructed of heavy-gauge galvanized iron. They need frequent inspection and cleaning.

Even the hood and duct system with fan suction may not prove adequate to prevent sweating of walls and ceilings, and to provide tolerable temperature conditions. It may thus be necessary to supplement them by the installation of wall fans or fans placed in other suitable positions in the plant to accomplish the desired circulation of air. Temperature conditions may be further improved by the installation of unit cooler fans for summer and unit heater fans for winter.

In rooms not infested with free steam during operation (except at cleaning-up time), but where numerous people are at work, such as may be the case in the butter print room, gravity ventilation may prove sufficient. In the absence of gravity flues, there is need of a suitably placed intake for fresh air and outlet for spent air. Improved air circulation is further provided by the installation of a fan, preferably in the air intake or outlet. For satisfactory temperature control in this room where butter is handled, there is need of an adequate section of brine or ammonia coils.

Factories located in sections of cities, or in other regions where the air is excessively polluted with dust, soot and other impurities, may have to resort to an air conditioning system that washes or filters the air. These systems preferably also provide for air tempering. In the case of washed air, the water spray through which the air current must pass, may be brine-cooled during hot weather and steam heated during cold weather. The filtering of air is usually done by drawing incoming air through a series of muslin cloths, suspended in a vault, or by the use of oil filters. In this case, the tempering of the filtered

air is accomplished by its passage over brine or ammonia coils for cooling, and over steam coils for heating.

The entire problem of providing the creamery with a satisfactory system of air conditioning is a very important one. The purity, temperature control, and humidity of the factory and office air have a direct and proven influence on the health, comfort and efficiency of the personnel, on the sanitary and mold conditions of the factory, and on the life of the equipment. The importance of this problem is of such magnitude as to merit serious attention in negotiations for the planning, construction and equipping of a new plant, and it suggests the wisdom on the part of the builder to give his considerations the benefit of the expert advice of a qualified air conditioning engineer.

The Store Room.—A spacious store room should be provided, so as to enable the creamery to carry a plentiful stock of supplies, packaging material, and cans. The store room should be of such size as to enable the creamery to take advantage of rebates by purchasing in quantities.

In the case of the one-story factory there is seldom enough room provided for a spacious store room and it may be advantageous in such cases to erect, or rent the use of a suitable rainproof shed, in convenient proximity to the factory. In the case of the creamery with more than one story, the second, or upper floor, generally serves as the store or stock room.

The store room should be so located and constructed that it can readily be kept clean and dry. A damp storage room harbors dangers that may prove most disastrous to the creamery. It invites mold growth on tubs, liners, wrappers and other packing material, and contributes to the rusting of the cans in stock, and to the caking of the butter salt.

If located on the first floor, as a part of the factory, it should be protected against free steam and leaky pipes. If a shed is used, the floor should be sufficiently elevated above ground to avoid dampness from below. If located on the second floor above the factory, every effort should be made to keep it closed against the moisture-saturated air from the factory. The elevator shaft should be housed-in and the housing should be equipped with self-closing doors in the factory leading to the store room. If a portion of the store room is located over the boiler room, care should be taken that the blow-off and pop-off valves discharge

not over the boiler, but through the walls to outside of the building. Where the roof is not insulated, moisture will condense on the under side in cold weather, causing frosting and dampness. The only permanently satisfactory means of avoiding this dampness is to seal the roof on the under side.

The Butter Cooler.—One or more cold rooms of suitable size, according to volume of peak make, is an integral part of the creamery. All butter intended for prints or rolls, where printing equipment other than the hand mold is used, must be hardened before printing. All printed butter is or should be returned to the cooler until it goes to the trade. Prints of unsalted butter, in fact, need freezing temperature or lower, in order to insure absence of deterioration upon arrival on the consumer's table. All butter, regardless of package, tubs, boxes or prints, needs to be held in the cooler until shipped or delivered. For the limited time the butter is held in the factory cooler (usually from a few days to several weeks), a temperature of around 40° F. or lower is suitable.

In creameries with artificial refrigeration, the butter cooler is equipped with one or more sections of brine pipes, sufficient in number and length, based on size of cooler and average temperature of brine, to maintain the desired cooler temepratune. Some creamery cold rooms are equipped with direct expansion ammonia coils. Their operation provides quicker cooling and lower temperatures, but their cooling function ceases as soon as the compressor is stopped. In order, therefore, to maintain the cooler temperature without operating the compressor 24 hours, provision must be made to store up cold while the compressor operates. This may be accomplished by the installation in the cold room of several sections of calcium chloride tubes which act as cold reservoirs.

The cooling coils may be fastened to the cooler walls or they may be suspended from the ceiling, being fastened by means of heavy rods to the joists of the floor above. In order to keep the cooler dry, drip pans are placed directly under the brine or ammonia pipe sections, that catch and carry off the melted frost. Dryness in the cooler is further promoted and the cooling efficiency improved by providing adequate circulation of air. This may be done by arranging for gravity circulation. One side of the pipe section carries a baffle or partition

that extends from the drip pan to within about 8 inches of the ceiling. The warm, moisture-laden air rises up along the baffled side to the top, passes over the refrigerating pipes and condenses its humidity on them, while the cold air drops from the opposite or open side of the drip pan, thus providing a continuous circulation of air and keeping the cooler dry.

In some installations the cooling is done by mechanically blowing air through small units of brine or ammonia coils. The unit cooler, with a motor-driven fan behind each cooling unit, is representative of this type of cooling arrangement. It is usually equipped with thermostatic control of the cooler temperature. It requires a separate line and pump direct from the brine tank.

The substantial construction and efficient insulation of the butter cooler are important for economy of refrigeration and to avoid early and costly repairs. A satisfactory and durable floor should have 4 inches of concrete on a solid foundation, then 2 layers of 2 inch cork board, dipped in asphalt and layed staggered. This is then covered with 4 inches of concrete and ½ inch of surfacing. For the walls 2 x 4 studs, placed 18 inches apart, are used. Against this framework of 2 x 4s is laid a layer of asphalt-dipped 2 inch cork. This is covered with a ½ inch layer of concrete or tar material, followed by a second layer of asphalt-dipped 2 inch cork and a final layer of ½ inch of concrete on tar material. The 2 x 4 studs are then removed and the outside of the wall of cork is finished with a layer of ½ inch of concrete or tar material.

For a permanent ceiling that will hold its insulation in place indefinitely, T beams are laid across, 24 inches apart, and the first layer of 2 inch cork blocks, asphalt-dipped, is laid inside the beams, their ends resting on the bottoms of the inverted Ts. Then a second layer of 2 inch, asphalt-dipped cork blocks is placed on top of the first layer, and the underside of the bottom layer is coated with ½ inch of concrete or tar material.

Standard, insulated and properly fitting refrigerator doors are the most economical, and loss of cold is further minimized by the installation, inside of the cooler door, of swinging twin vestibule doors. It is further advantageous to provide an opening with insulated shutter in one of the outside walls. The use of this opening in cold weather may provide the necessary cold room refrigeration, without operating the compressor.

In the case of creameries with natural ice, the ice bunkers are preferably arranged along similar lines as the sections of refrigerating pipes referred to in previous paragraphs, providing drip pans and using baffles to promote circulation of air and to keep the cold room dry. It is usually a factor of economy, wherever feasible, to build the ice house into the outside wall of the creamery cold room. Cutting a row of openings of ample size in the wall between cold room and ice house, at top and bottom, utilizes the cold air of the ice house and provides ventilation in the butter cooler. The cold air thus enters the cooler from the ice house through the bottom openings, while the warm, humid air escapes from the cooler to the ice house through the top openings. A cistern under the floor of the ice house will serve as a reservoir for the ice water, from where it may be pumped through the cream coolers.

The butter cooler should be so located as to be within convenient reach of the churns and preferably adjacent to the butter print room. Thus the butter trucks loaded with butter at the churns, are readily and quickly wheeled into the cooler. Through a door between butter cooler and print room, the chilled butter is conveniently transferred to the butter cutters and the wrapped prints returned to the cooler.

Testing Room.—A suitable room for testing milk and cream for butter fat and butter for moisture and salt is indispensable for satisfactory operation. This room should be installed in convenient proximity of the churns. It should be of adequate size for the volume of business, and provided with acid resistant drains, ample circulation of air and ventilation to protect the health and efficiency of the personnel, substantial pyramids on which to mount the Babcock testers, and suitable facilities for accurate weighing of samples, handling of acid, hot water supply, water baths for tempering cream samples and cream tests, and with ample sink capacity for soaking and washing the testing equipment. The tables and sinks are preferably lined with lead sheeting, or otherwise treated with acid-proof surfacing. Proper provision should be made also for such disposition of the waste acid from the tests, as to eliminate the danger of damage to concrete floor and floor drain.

Lavatories.—One wash room each, for the male and female personnel, installed in a suitable location, should be provided

with ample toilets, washing facilities, with hot and cold water, lockers for clothes and showers. These rooms need to be of adequate size and such arrangement as to facilitate general sanitation, order and cleanliness. They should be provided with proper ventilation and light.

There is need further of wash basins with hot and cold water and approved plumbing to take care of the waste water, located in different parts of the manufacturing rooms. This is especially necessary near the churns, in the print room and wherever the routine of work is associated with the handling of butter, and where, therefore, clean hands and convenient facilities for washing them are indispensable to decency and sanitation.

Power Room.—It has been found advantageous, wherever possible, to assemble such power equipment as engines, compressors, well pumps, brine pumps, etc. in a separate room. When designing the building of a new creamery, therefore, it is advisable to plan for such a room and to provide for sufficient space and suitable arrangement to afford ready access to all machines for operation and repairs, and ready visibility of gauges, motors, etc.

Repair Shop.—The need of facilities for the prompt repair of equipment and machinery in the creamery is obvious. Ability to make such repairs promptly when needed, often protects the plant against costly loss of product or permanent damage to equipment, and accidents to employees. The tool bench may find a suitable place in the boiler room or stock room, otherwise a separate room of dimensions that will accommodate the handling of pipes of standard length may be provided.

Boiler Room.—The size and height of the boiler room must necessarily be governed by the size and type of boiler that is to be installed. It should be of such dimensions as to facilitate flue cleaning, to make all parts readily accessible for repairs, and to accommodate such accessories as feed water tank and pump. Creameries of average size, that do not condense or dry their buttermilk, usually have only one boiler. A creamery with a butter output of approximately 1,000,000 pounds per year, needs a boiler capacity of about 50 H. P. and a working pressure of about 100 pounds. The horse power is determined by the square feet of heating surface. Each horse power requires

10 square feet of heating surface. The working pressure refers to the strength of the boiler. It is determined by the weight of its construction, such as the thickness of the steel shell, the bolts and other parts.

Of the three general types of boiler, i.e., the water tube boiler, the return-flue boiler and the Scotch Marine boiler, the last named appears to be most suitable for average creamery conditions. The water tube boiler is practically out of the question because of its high cost and its requirement of a complicated setting. It is better adapted to larger installations than are required for creamery purposes, such as installations of over 200 H. P. capacity. The Scotch Marine is a fire-tube boiler. While, for coal firing without a stoker, its efficiency may be slightly less than that of the other types, such as the Horizontal Return Flue boiler, it has advantages that make it preferable and more economical over a period of years. It does not require as high a boiler room. It has a large fire box and is quick acting, which is of advantage in creamery work, where it is often necessary to "get up" steam quickly, such as where an additional unexpected load of cream comes in. It is self contained, easily installed and moved, and requires no brick lining to keep up. It likewise has no brick that must be heated before steam is up. Furthermore, in a creamery of average capacity and having one boiler only, repairs tend to delay operation and to embarrass the factory routine. Brick-lined boilers need frequent repairs that are eliminated in the case of the Scotch Marine boiler. In addition, the average creamery lacks the services of a boiler expert who would quickly discover the need of repairs and would be capable of their proper care.

Creamery Smoke Stack.—Considering service over a period of years, the brick chimney, properly constructed and reinforced, in all probability proves more economical than the steel stack. The sulphur fumes from coal smoke and from natural gas smoke, cause comparatively rapid corrosion. Steel smoke stacks last about 10 years, under average conditions. They need repainting about every other year. In the case of oil or wood smoke, the sulphur fumes are less prevalent. The initial cost of the brick chimney, however, is considerably greater, chiefly because of the added need of a solid foundation in the ground. Furthermore, the brick stack should be lined with tile in order to prevent the fumes from deteriorating the mortar.

The minimum height of the chimney, that will provide a satisfactory draft, varies with type of boiler, different fuels and diameter of stack. The smaller and more circuitous the gas passages, the higher the stack required. Wood and free-burning bituminous coal require less height of stack than slow burning coal. The smaller the diameter the higher must be the stack. For a 50 H. P. creamery boiler, when using average quality coal, a 2 feet diameter stack, fifty feet high, is considered ample.

Coal Stokers, Oil and Gas Burners for the Creamery Boiler.—Stokers for coal-burning boilers, because of their better and more uniform control of the fire bed, assist in the economic firing of the boiler. They also help to diminish the smoke nuisance.

For the burning of oil and gas, three general types of burners are available, namely, 1.) straight steam jet, steam-atomizing burners; 2.) rotary burners; and 3.) combination gas and oil burners.

The Straight Jet burner is the simplest and cheapest. It is not very efficient in fuel economy, however. In addition it is associated with the danger of impinging the flame on localized portions of the metal, causing blisters, weak spots and early deterioration, necessitating early repairs.

The Rotary burner is of high initial cost and involves considerable added equipment, such as motor and pump. The character and effect of its flame, however, have distinct advantages. It gives the blast a rotating, diffused flame that does not impinge on localized metal surfaces. It does not damage the boiler. Its performance has proved it to be from 15 to 25% more efficient than the straight jet burner, paying for its greater initial cost in saving fuel over a year's time. It is considered the cheaper burner in the "long run."

The Combination Gas and Oil burner may prove most economical where both gas and oil are available and where it may happen that gas is more economical part of the year, while oil is more economical for the remainder of the time. Though the initial cost of the combination burner is somewhat greater than that of the single-purpose burner, the combination burner, making possible the use of gas or oil, according to the shifting economy of either, may effect savings that will soon pay for the extra initial cost and, in addition, may accomplish a considerable reduction in the annual fuel cost.

Heating the Building.—The temperature control of factory and office was briefly discussed in connection with air conditioning under the heading "Ventilation," earlier in this chapter.

In localities with cold winters, the heating of the building is usually done most economically by the proper distribution of a sufficient number of steam radiators to afford ample radiation of heat, using exhaust steam, if available. Where the machinery is driven by gas or electric power, and in the absence of steam engines and steam-driven pumps, a low pressure steam line direct from the boiler to the steam radiators may serve the purpose. In such case the steam exhaust and condensate from the radiators are best returned to the boiler feed water system. The steam and return pipes should not be laid in the floors nor hidden in walls and partitions. Aside from their inaccessibility for repairs and replacement, hidden steam and hot water lines attract ants, termites, cockroaches and rodents.

CHAPTER III

STEAM POWER, REFRIGERATION AND WATER-TEMPERING SYSTEMS

THE STEAM SYSTEM

In this age of electric and gas engine power, the creamery machinery is practically exclusively equipped with direct motor drive for each piece of equipment, and the steam requirements are limited to steam used for the pasteurization of milk, cream and possibly of the water needed for washing the butter, rinsing down the cream vats and controlling the moisture of butter, for cleaning and sterilizing of the factory equipment, operating the can washer, and for heating the building.

Sources of Steam.—In some localities steam may be available from a municipal or commercial power plant. In many cases this steam supply is purchasable at a price materially lower than the creamery's cost of producing its own steam at prevailing fuel prices. This, together with elimination of the necessity of investing money in providing its own steam plant and its upkeep, renders the purchase of steam economically attractive. The average creamery, however, has no access to purchased steam and must rely on its own steam production.

Steam Boilers and Accessories.—The type and size of boiler suitable for creamery use, coal stokers and gas and oil burners, were briefly discussed under "Boiler Room" in Chapter II. The convenience, elimination of dust and soot, and the economy of burning gas or oil, where cheap natural gas or crude oil are available, give the use of these fuels obvious advantages over coal.

In the case of the bricked-in boiler, it is important to allow the mortar to thoroughly dry out before the boiler is put into service, in order to prevent early cracking in the brick work. If a second hand boiler, it should be given a thorough and careful inspection as to its condition and safety. For maximum economy, the boiler should be no larger than necessary to satisfy the peak steam requirements, when operating with a load condition approximately 125 per cent of the rated capacity of the boiler. Under average creamery conditions, nothing is gained by

a larger boiler. Undersize boilers use fuel uneconomically, and forcing them places a strain on the boiler. In the case of coal firing of undersized boilers, smoke abatement may become a serious problem.

The steam gauges on the boiler should be of high quality and dependably checked for accuracy. The water column should be kept clean and free from cracks. The water should be blown down each day and the height of the water in the column checked by the use of the trycocks on the column.

The blow-down cock should connect with the outside of the factory and should be used daily. The safety or pop-off valve should be set to blow off at the stipulated boiler pressure, and kept in proper operating condition. It should be tested daily, either by raising the pressure until the safety blows off, or by gently raising the valve from its seat by hand. If it sticks, it should be examined, the cause removed, and the valve readjusted to the desired pressure. It is advisable also to recheck the steam gauge for accuracy.

The fouling of the heating surface either inside or outside (in the case of the fire tube boiler, with soot on the inside and scale on the outside of the tubes), greatly decreases the capacity and the efficiency of the boiler. It prolongs "getting up" steam and it may cause burning of the boiler metal. The inside of the tubes should be cleaned regularly, depending on the kind and quality of fuel used. For coal of average quality these flues should be cleaned weekly. The boiler should be examined regularly for scale formation and sludge.

Boiler Feed Water.—Boiler scale and sludge are formed by hardness in the water. There are two kinds of hardness; namely, permanent hardness and temporary hardness. The permanent hardness is caused by the presence in the water of calcium sulphate. This is precipitated at high temperatures (300° F. or above) and forms a hard scale. The temporary hardness is caused by the presence of carbonates of calcium and magnesium, which are precipitated at 212° F. In the absence of other hardness, the carbonates form a soft precipitate and are responsible for much of the accumulation of sludge in the boiler. In the presence of sulphate hardness some of the carbonates in admixture with the sulphates may burn onto the heating surface, increasing the volume of hard scale. The water may also contain acid which, unless neutralized, causes corrosion and pitting.

Because of their formation of scale in the boiler, hard waters, unless properly treated, lower fuel economy, prolong the time necessary to "get up" steam and may cause damage to the boiler due to burning of the boiler metal. It is, therefore, important to use boiler feed water that is, or has been made reasonably free from hardness. The hardness of water is arbitrarily expressed in terms of grains of solids per gallon, as follows:

soft water = 1-10 grains per gallon
moderately hard water = 10-20 grains per gallon
very hard water = above 25 grains per gallon

By proper treatment of the hard water, the hardness is dissipated and scale formation prevented. Since the water varies in composition with locality, and in the absence of facilities and technical knowledge for water analyses, it is usually wisdom on the part of the average creamery to consult a reliable boiler compound firm regarding the kind of treatment its particular boiler feed water requires. The service department of these firms is generally equipped to make an accurate analysis of the water, and to prescribe and supply the particular treatment needed.

Heating the Boiler Feed Water.—Fuel economy and rapidity of getting up steam are generally improved and the tendency of scale formation diminished, by heating the boiler feed water before it enters the boiler. It is, therefore, good practice for the creamery to provide a suitable means for this purpose. For boilers no larger than those needed in the average creamery, open heaters appear most practical. These simply consist of a tank of suitable size, preferably installed in the boiler room, in which the feed water is heated by exhaust steam, and steam condensate derived from steam radiators, steam jacketed equipment and steam piston pumps. These open feed water heaters are usually provided with relief valves and overflow. In case of exhaust steam from steam engines, suitable oil separators should be provided.

Under some conditions, the use of closed heaters may be of advantage. In these heaters the steam and water do not come in direct contact with each other. They are closed drums in which either the steam or the water passes through tubes. Their disadvantage lies in the need of somewhat more expensive equipment, in the fact that they do not heat the water to quite as high a temperature, and that they may become scaled and

need cleaning. On the other hand, they eliminate the danger of getting oil into the feed water.

Feed Water Pumps and Injectors.—For the creamery boiler the steam injector usually answers the purpose of feeding the water into the boiler. Its advantage lies in its cheapness, compactness and absence of wearing parts. It has the drawback, however, of limited reliability, of inability to function satisfactorily with water at a temperature much above 100° F. and its need of adequate steam pressure. Because of these drawbacks, it has been found advisable to supplement the injector by the installation of a boiler feed pump, the performance of which is more positive and, therefore, more dependable. The pump has the added advantage of facilitating the continuous feeding of treated water.

The most suitable boiler feed pump for creamery purposes appears to be the simple, direct-acting simplex or duplex pump with piston and water cylinder. This is usually steam-driven, but may have electric drive, in which case its function is entirely independent of the steam pressure carried in the boiler.

Steam Purifiers.—In direct-steam pasteurization of the cream, such as is used especially in connection with cream deodorization, it is desirable to have dry and clean steam in order to avoid excessive dilution of the cream with steam condensate, and to keep steam impurities out of the cream. For this purpose a steam purifier may be installed in the steam supply line to the pasteurizer, placing the steam purifier as near as practicable to the pasteurizing unit. The drain of the purifier is advantageously connected with a small steam trap.

The mechanism of the steam purifier is simple. It consists principally of a baffled container through which the steam must pass. The baffle takes impurities such as sulphate scale, etc., and some of the water, out of the steam. The impurities deposit on the baffle and the water escapes through the steam trap. The baffle needs cleaning at reasonable intervals. It should, therefore, be examined from time to time (about every six months) and, if coated with steam impurities, it should be cleaned. This is readily done by removing the baffle cage and soaking it in a 10% solution of hydrochloric (muriatic) acid.

Hand Firing of Boiler.—In the case of fuel other than gas or oil, the quality of the fuel and the manner of firing have a

marked influence on fuel economy. Generally speaking, the better grades of coal are more economical than the cheapest grades, unless distance and means of transportation render their cost prohibitive.

In the absence of a stoker, and even of a regular fireman, as is often the case in the small creamery where the firing is done by anyone in the factory, the service of the boiler is usually irregular, the general tendency is to carry a fire bed of excessive depth, and to do the firing at relatively long intervals and in large quantities at each time. This is contrary to the best practice and conducive to objectionable clinkering with the usual type of coal used. The best depth of the fire bed varies with type of coal and the amount of gases it contains. Generally speaking, the higher the volatile material in the coal, the larger the combustion space required, the thinner should be the fire bed, and the smaller the quantity of coal to be added at each interval. The Babcock and Wilcox Company[1] offer the following suggestions for general operating conditions for hand firing:

1.) "Semi-bituminous coals, such as Pocahontas, require fire beds from 10 to 14 inches thick; fresh coal should be fired at intervals of 10 to 20 minutes and sufficient coal charged at each firing to maintain a uniform thickness.

2.) "Bituminous coals from the Pittsburgh Region require fires from 4 to 6 inches thick, and should be fired often and in small charges.

3.) "Kentucky, Tennessee, Ohio and Illinois coals require a thickness of from 4 to 6 inches.

4.) "Free burning coals from Rock Springs, Wyoming, require from 6 to 8 inches, while the poorer grades of Montana, Utah and Washington bituminous coals require a depth of about 4 inches.

5.) "For Lignites a fuel bed of 4 to 6 inches can be maintained and the coal should be fired in small quantities." Lignites are brown coals usually bearing traces of woody structure.

The average creamery boiler is not well adapted for burning mill refuse such as sawdust, chips, blocks, etc., because of lack of sufficient furnace volume. The cheapness of this fuel, however, justifies consideration of its use in the creamery, where available, and while it requires almost constant firing, its use

is practicable in the presence of a special grate adapted to such refuse.

Smoke Abatement.—Creameries using bituminous coal and that are located in towns and cities, not infrequently find difficulty in complying with local smoke nuisance ordinances. In many cases the principal cause of smoke complaints is traceable to faulty handling of fuel and boiler by the creamery. In other cases the fundamental trouble lies in the fact that the boiler is too small for the steam requirements, and its forcing necessitates the use of more fuel than the size of the combustion chamber is capable of properly utilizing.

Smoke and soot are largely the result of incomplete combustion of the volatile hydrocarbons. Incomplete combustion of the hydrocarbon is caused by an insufficient supply of oxygen left to combine with the carbon after the hydrogen has been satisfied. If not enough oxygen is present, or if the temperature is reduced below that necessary for the combining of carbon and oxygen, the carbon will not be consumed and it will escape as soot and smoke.

The first requisite to limit the amount of smoke produced, therefore, is to have the boiler of such size as to permit of normal operation without undue forcing with fuel. In the second place, the firing must be done in such a manner as to permit maximum combustion of the volatile gases. This means firing at short intervals and in reasonable quantities, scattering the coal quickly and evenly over the entire surface of the fire bed, maintaining a low, even depth of fire bed, and working the fire bed as little as possible. It is for this reason that the use of a good stoker, because of its gradual and even feeding of the fuel, is a great help in efforts toward smokelessness, although it should not be looked upon as a cure-all under all combinations of conditions.

Any means of extending the travel of the gases under the heated brick work, before they contact the boiler heating surfaces, such as extension of the boiler furnace, will assist in diminishing the smoke. It is here again where the stoker principle is of assistance by favoring the time of combustion exposure. A further means to diminish the volume of smoke, lies in the use of heated arches and in introducing air over the fires. Under certain combinations of conditions, change to a better grade of coal that contains less volatile material, must be resorted

to as the final answer to the permanent abatement of the smoke nuisance.

THE REFRIGERATING SYSTEM

Refrigeration plays an important rôle in the successful operation of the creamery. Ample facilities are needed for proper control of the cold room temperature, and for rapid and sufficient cooling of the pasteurized cream, starter milk, and water used for washing the butter.

Natural Ice.—For small creameries located in northern climes natural ice usually furnishes the most economical refrigeration. This requires an ice house for storage. The cold room then is usually refrigerated by filling ice racks located at one side or under the ceiling, as discussed under "Butter Cooler" in Chapter II. The purchase of artificial ice in the absence of natural ice seldom furnishes economical refrigeration.

With ice as the refrigerant, the cooling of milk, cream and starter is generally done by circulating ice water through the coil or jacket of the vat. In order to expedite the cooling and to make possible the attainment of lower temperatures, the ice may be mixed with salt and the resulting brine used, at least for finishing the cooling to the final temperature.

When cooling with ice only, the extent of temperature reduction is obviously limited and is often inadequate. It is difficult to maintain the cold room temperature much below 50° F., and the cooling of the cream to churning temperature, is relatively slow, and not infrequently the low temperature needed for best results cannot be reached.

Mechanical Refrigeration.—The advent of mechanical refrigeration has vastly simplified the attainment of satisfactory refrigeration in the creamery, and has solved the problem of controlling the cold room temperature and the cooling temperatures in manufacture. It is adapted for use in every creamery, regardless of volume of manufacture and geographical location. Its outstanding advantages of greater convenience, more constant supply of cold, wider range of cooling temperatures, and greater rapidity of heat exchange, have resulted in its universal adoption.

In all mechanical refrigerating systems, the underlying principle of heat exchange is based on the absorption of heat by

evaporation of liquids with low volatilizing points, when released from high pressure to low pressure, such as ammonia, sulphur-dioxide, carbonic acid, ethyl chloride, etc. Ammonia is by far the most common refrigerant used in creameries of this con-

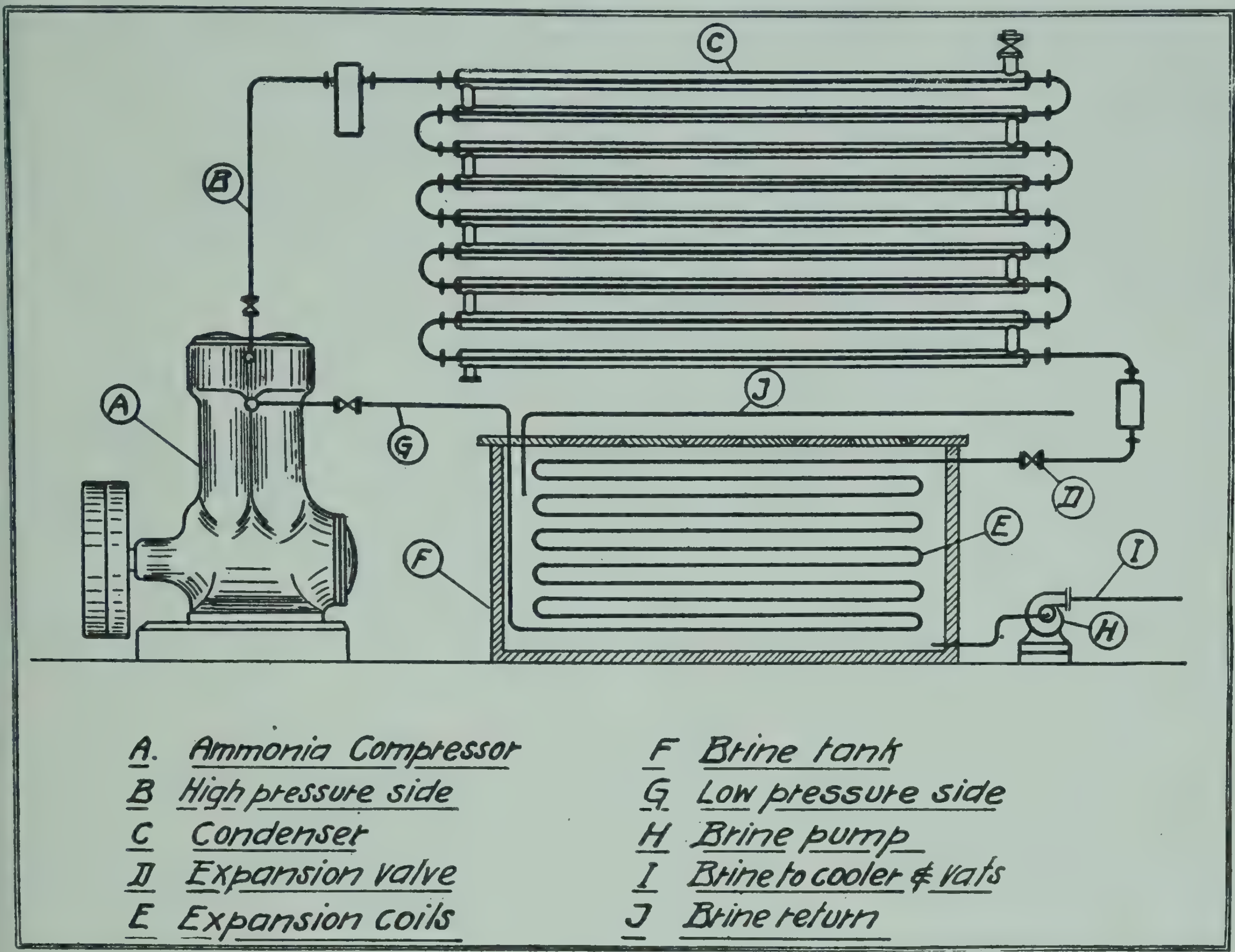


Fig. 10. Refrigeration plant

tinent. American ammonia refrigerating machines are of two types; namely, the compression system and the absorption system. The compression system, because of greater simplicity and compactness, has been given preference and is now used in creameries almost exclusively.

Ammonia Compressors.—In the compression system the ammonia gas is compressed under great pressure. The compressed gas is reduced to the liquid state by passing through a tubular condenser cooled by cold water. The liquid ammonia then passes through a needle valve (the expansion valve) into expansion pipes. By passing into these larger pipes through the needle valve the pressure is released, much diminished, the liquid ammonia expands into a gas; it vaporizes. This expansion or vaporization requires and is accompanied by the absorption of a great deal of heat. This, in turn, produces intense cold,

thus lowering the temperature of the medium—air, brine, or dairy product—that surrounds the expansion coils. The ammonia gas is then rapidly pumped back into the compressor where it is again compressed, converted into the liquid state and the cycle repeated. For full details on construction, installation and operation of ammonia compressors, the reader is referred to manuals on mechanical refrigeration.

With mechanical refrigeration, the cooling of the creamery cold room and of the milk, cream and other dairy products, may be done by the use of the brine system, or by the direct expansion system.

THE BRINE SYSTEM

The majority of the creameries, and particularly those of limited volume, are as yet doing their cooling with brine. In this system the cold produced by evaporation of ammonia in the expansion coils cools the brine and the cold brine serves as the refrigerant medium that performs the desired cooling, where wanted.

Cooling the Brine.—The refrigerating system with brine cooling is shown in Fig. 10. From ammonia compressor (A) the compressed ammonia is pumped from the high pressure side at (B) through condenser (C) and into the receiver (not shown) located directly below the condenser. From the receiver it passes through expansion valve (D) into coils (E) in brine tank (F), and the ammonia gas is pumped back to the low pressure side of the compressor through pipe (G). The cold brine is pumped by pump (H) through pipe (I) to cold room, vats, and other places where cold is needed. It returns to the brine tank through pipe (J), entering the brine tank at a point opposite to the outlet in order to insure proper circulation and efficient cooling. The return pipe (J) terminates below the surface of the brine in the tank in order to avoid excessive absorption of CO_2 from the air.

Kinds of Brine.—The brine used is either salt brine or calcium chloride brine. Salt brine has the advantage of freedom from bitter taste. It should be used in all cases where there is danger of brine leaking into the cream. Salt brine, however, is very corrosive. Calcium chloride brine has an intense bitter taste and its leakage into cream jeopardizes the flavor of the

butter. It has the advantage, however, of being somewhat less corrosive and of permitting of lower temperatures without freezing.

Brine Tanks.—The brine tanks used in creameries are principally of two types; namely, the old style tank without mechanical agitator, and the new style tank, with trunk coil system and propeller agitator.

The old style tank is usually of square shape, or nearly so, and equipped with standard-pipe expansion coils into which the ammonia is fed from the receiver through the needle valve (expansion valve). Having no mechanical agitator, brine circulation in this tank is negligible. Even with the intake of the return brine located at the opposite end of the outlet of the tank, as it should be, the movement of brine in the tank is limited to the volume of brine flowing to the cream cooler and the cold rooms, and when circulation through the cooling equipment is stopped the brine in the brine tank is completely at rest.

The new style brine tank, with agitator and trunk coil system, is oblong in form. Its ammonia coils are V-shape and arranged along one side of the tank, with a partition between coils and the free space. A high speed propeller-agitator at one end of the tank, draws the brine through the coil side of the partition and forces it back through the free side to the opposite end where it again enters circulation through the coil compartment, causing continuous circulation of the brine over the ammonia coils at a relatively high velocity. In addition, these V-shape ammonia coils are fed with ammonia through a float valve installed between condenser and expansion coils, that permits a larger controlled amount of liquid ammonia to pass into the expansion coils, and a better distribution of its vaporization throughout the coils, thereby making for increased vaporization of ammonia, a larger area of active heat transfer, and increased cooling efficiency.

Advantages of Trunk System Brine Tank.—As seen from the above description, the new style, oblong brine tank with partitioned-off V-shape expansion coils, high-speed propeller agitator, and float-controlled liquid ammonia, is more efficient than the old style, square tank with standard-pipe expansion coils, supplied with liquid ammonia through a hand-operated expansion valve, and without mechanical agitator.

The intensity of heat transfer is directly influenced by the rapidity with which the brine passes over the expansion coils. The greater the velocity of circulation in the brine tank, the more rapid the absorption of heat from the brine, the quicker the brine cools, and the lower the temperature that can be attained. According to Jer and Soule[2] the additional heat transmission resulting from the circulation of a liquid is approximately proportional to the cube root of the increase of the flow velocity of the liquid. In the old style brine tank, without mechanical agitator, the almost static state of the brine practically eliminates the factor of velocity of circulation as a means to increase heat transfer and expedite cooling. In the new style brine tank, with propeller agitator, the high velocity of brine circulation materially increases heat transfer and speeds up the cooling.

In addition, the heat transfer is accentuated by the float valve arrangement that provides a better distribution of vaporization of ammonia and a larger area of active heat transfer. Furthermore, the fact that the expansion coils are V-shape and that their bottom inlet header receives liquid ammonia and their top outlet header expels the gas, shortens the travel of ammonia and gives it the type of direction (upward) that assists the escape of the gas bubbles. In the old style brine tank the ammonia must travel horizontally back and forth through the standard pipe sections, retarding its movement, decreasing the area of active heat transfer, and hindering expulsion of the gas.

For these numerous reasons the cooling efficiency of the trunk style brine tank has proved much superior to that of the old style. It has demonstrated its ability to utilize the refrigerating capacity of the compressor more nearly up to its full capacity, in fact, it makes possible the use of a smaller capacity compressor.

Capacity of Brine Tank.—In an efficient brine cooling system the brine tank should be large enough to keep the top sections of the expansion coils covered with brine, with the brine in full circulation through equipment and cold rooms. The volume of brine necessary to maintain the desired temperature during the working day for any size creamery, necessarily depends on the efficiency of heat transfer in the brine tank. Thus a creamery manufacturing from one to two million pounds of

butter may need a brine tank capacity of approximately 4,000 to 5,000 gallons, in the case of the old style brine tank without mechanical agitator, while a 3,000 gallon brine tank of the new style, with propeller agitator, has proved ample for the same volume of production.

Measuring the Brine Tank.—When preparing the brine it is necessary to know accurately the capacity of the brine tank. For this purpose the cubic content of the brine tank must be determined, measuring the depth from bottom to the level to which the brine rises when all the brine is pumped back into the tank from the system. One cubic foot holds 7½ gallons. Allowance must be made also for the ammonia coils and headers in the tank, by deducting from the cubical capacity of the tank the gallons displaced by these coils and headers. The number of gallons of brine displaced per foot of ammonia coils of different sizes is given below:

Table 5. Gallons Displaced per Foot of Pipes of Different Sizes

External Diam. of Submerged Piping Inches	Gals. Displaced per Foot of Pipe Length	External Diam. of Submerged Piping Inches	Gals. Displaced per Foot of Pipe Length
1–¼	0.064	2	0.163
1–½	0.091	2–½	0.255
1–⅝	0.107	3	0.367
1–¾	0.124	4	0.653
1–⅞	0.144	5	1.020

Strength of Brine.—The strength of the brine influences its corrosive tendencies, its freedom from crystallizing out, and its ease of pumping. A strong brine is less corrosive than a weak brine. On the other hand excessive strength invites the formation of crystals and greatly augments the load of the brine pump. It is important, therefore, to maintain the brine at a strength that will minimize corrosion, consistent with ease of pumping and freedom from crystallization. For average creamery refrigeration a density of 1.17 to 1.18 at 60° F. or a salimeter reading of 85° to 89° is most suitable. To prepare such a brine, use 225 lbs. of salt (sodium chloride) or 260 lbs. of calcium chloride per 100 gallons of water. The freezing point of salt brine of a density

of 1.17 is about 5° F., but brine of this density will not congeal nor appreciably thicken above 0° F. The freezing point of calcium chloride brine at a density of 1.18 is –1.5° F. For ordinary creamery purposes these freezing points are sufficiently low, and also high enough to avoid freezing of the brine. It is, therefore, neither necessary nor desirable to use brine of greater density than above indicated.

Making Up Brine.—The salt or calcium chloride should be dissolved before it reaches the brine tank. "Dumping" the undissolved material into the brine tank causes incomplete solution and deposit in the bottom of the brine tank, and renders unsatisfactory the control of the strength of the brine.

The particular system of dissolving the salt or calcium chloride and of adding it to the brine tank, must of necessity vary

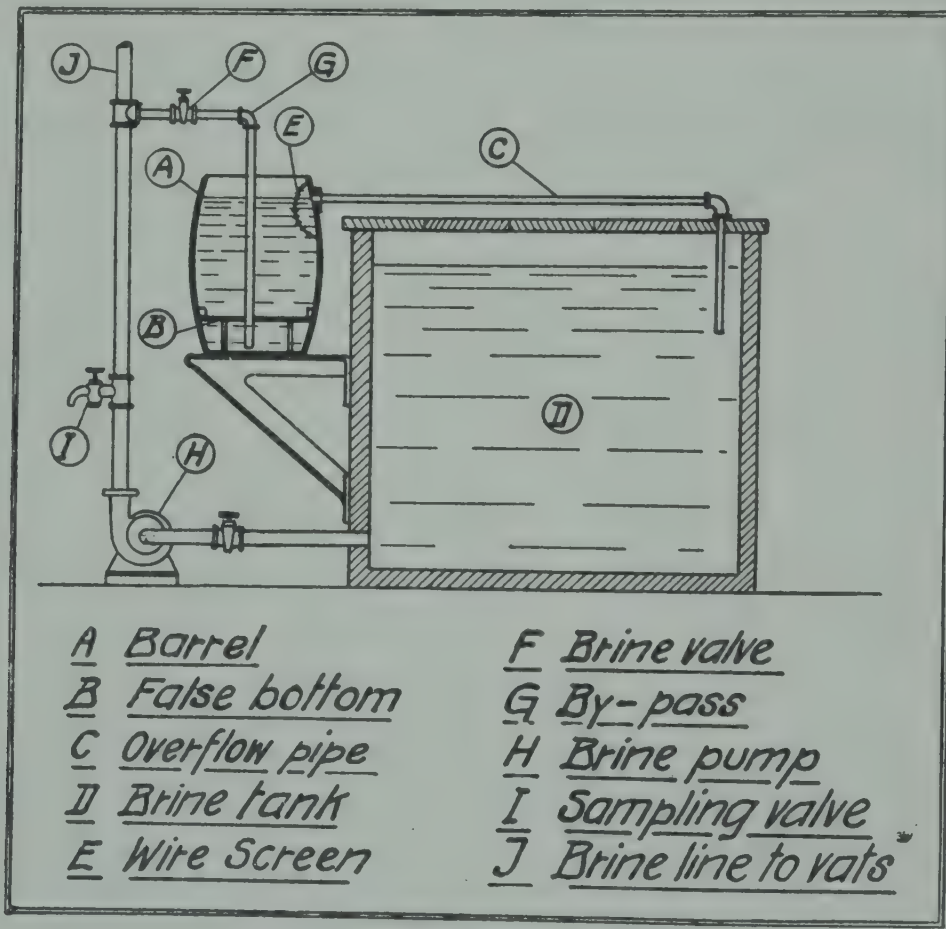


Fig. 11. Making up brine

with the general arrangement and operation of the factory equipment. No one system is adapted to every creamery. The following description may serve to convey a general idea of a practical system for making up the brine:

Use a barrel (A) with false bottom (B) as shown in diagram Fig. 11. Near the top of the barrel there is a hole into which is screwed the threaded end of the pipe (C) leading to the brine

tank (D). This opening is equipped with a piece of wire screen (E) to keep dirt and other foreign matter out of the brine in the tank. The false bottom is preferably made of 7/8-inch board perforated with numerous holes about 1/8 inch in diameter. This board is provided also with a two-inch hole to accommodate the water hose. The false bottom is nailed on 2″ x 4″ blocks and to the side of the barrel so that it will not float.

When making up a new batch of brine, stick the water hose through the two-inch board in the false bottom. Fill the barrel a little more than half full of the dry salt or calcium chloride and run water through the barrel. It is advisable to open the water valve just enough so that the brine that flows out of the barrel is approximately of the desired density. This may be readily determined by taking samples at the overflow and testing them with the hydrometer or salometer. Stir the salt or calcium chloride in the barrel occasionally, so as to prevent caking and honey-combing. As fast as the material dissolves add more until the entire amount to be added is used up. In case all the water required to make up the desired volume of brine has been used up before all the salt or calcium chloride is dissolved, circulate the brine from the brine tank through the barrel, as directed in the next paragraph.

When the purpose of adding salt or calcium chloride is merely to strengthen the brine that is already in the brine tank, open the brine valve (F) in the "by-pass" (G) so that some brine is allowed to pass from the tank into the barrel through the pipe that extends through the false bottom. Then proceed as directed for making up new batch of brine, except that no water is added.

Loss and Dilution of Brine.—There is a constant tendency to lose or weaken the brine used in the creamery, particularly in the operation of coil vats in which the cooling is successively done with water and brine.

Loss of brine is indicated by the low brine level in the brine tank. Since brine is an item of expense, it is important to make a thorough check-up on the system when the brine level recedes, in order to determine and eliminate the cause of the brine losses. These losses may be due to carelessness in leaving the brine valve open, that drains the contents of the vat coil after brine cooling. Or, the cause may lie in not running the vat coil long enough at the conclusion of brine cooling and after the brine to the vat has been shut off, to pump all the brine out

of the coil back into the brine tank. It usually takes about five minutes running, with coil vent open, to empty the coil. In the case of the vertical coil, it is necessary to push the brine out of the coil with compressed air. Whatever the cause of a low brine level in the brine tank may be, the brine should be brought back to the proper level by filling up with added brine.

Dilution of the brine is indicated by an abnormally high brine level or by overflowing of the brine tank. A high brine level is usually due to running water into the brine tank. This may happen when the vat coil is not completely emptied of its water before the brine is turned on. The extent of the dilution is readily determined by testing the brine for density with the hydrometer. If its specific gravity at 60° F. is considerably be-

Table 6. Brine Density Chart

Pounds of Salt or Calcium Chloride to Add at Different Densities of Brine to Raise Specific Gravity to 1.17

Salt Brine				Calcium Chloride Brine			
Specific Gravity at 60° F.	Salt to Add per 100 Gals. of Brine Pounds	Specific Gravity at 60° F.	Salt to Add per 100 Gals. of Brine Pounds	Specific Gravity at 60° F.	Calcium Chloride to Add per 100 Gals. of Brine Pounds	Specific Gravity at 60° F.	Calcium Chloride to Add per 100 Gals. of Brine Pounds
1.170	none	1.147	36.4	1.170	none	1.148	47
1.168	3.9	1.145	40.0	1.168	5	1.145	52
1.165	7.7	1.143	43.5	1.165	10	1.142	57
1.163	11.6	1.140	47.1	1.162	16	1.140	61
1.160	15.2	1.138	50.8	1.160	21	1.137	66
1.158	19.0	1.136	54.4	1.157	27	1.135	70
1.156	22.6	1.134	58.0	1.155	32	1.132	75
1.154	26.2	1.132	61.3	1.152	38	1.130	79
1.151	30.7	1.130	64.8	1.150	43		
1.149	32.9						

Gallons of Water to Add to Reduce Specific Gravity of Brine to 1.17

Salt Brine		Calcium Chloride Brine	
Specific Gravity at 60° F.	Water to Add per 100 Gals of Brine Gallons	Specific Gravity at 60° F.	Water to Add per 100 Gals. of Brine Gallons
1.180	5	1.180	3
1.185	9	1.185	5
1.190	13	1.190	8
		1.200	12

low 1.17, the brine should be reinforced by the addition of the proper amount of salt or calcium chloride to regain the desired density. Such corrections are facilitated by consulting the brine density chart shown in Table 6.

The successful prevention of loss or dilution of brine requires proper appreciation on the part of the operator, that loss or dilution of brine is costly to the creamery. He must be brine-conscious.

Brine Alarm Systems.—Avoidance of heavy loss and excessive dilution of brine, such as may occur accidentally at any time, is most effectively provided by the installation of a brine-level alarm that signals when the brine level drops below or rises above the normal range. Numerous, more or less elaborate systems are available for this purpose. For a simple and inexpensive, but dependable alarm, that may be assembled by home talent, the following system is suggested as one of proven service:

The alarm consists of a float with rod and rod guide, an automatic electric switch, a six volt transformer and a six volt bell. The contacts on the switch may be made so that the bell rings when the brine level is about 1½ inches above normal, or about 1½ inches below normal. This spacing of contacts may have to be varied according to volume of brine needed in circulation, as determined by the amount of brine that is taken out of the tank when all the vats are operating, and when all the brine has been returned to the tank when the brine is not being used.

The float should not be located in a position in the brine tank where the current is severe, such as too near the return of the brine, as the current may keep it bobbing and cause the float rod to bind in the guide. In the case of a brine tank with mechanical agitator, the float needs to be baffled in order to keep it free from the violent current produced by the agitator. The float may be made of a one inch board of wood to the top and bottom of which is fastened a two inch cork board about 12 inches square. Or, a cylindrical float about 12 inches in diameter and 3 inches deep, made of copper, may be used.

CORROSIVENESS OF BRINE

General Principles of Corrosion in Refrigerating Brine.—Corrosion in the refrigerating industry has been the subject of

intensive study by the Corrosion Committee of the American Society of Refrigerating Engineers. On the basis of the generally accepted electrochemical theory of corrosion, discussed by Whiteman, Chappell and Roberts[3], the corroding metal goes into solution at an anode area, and hydrogen is simultaneously deposited at a cathode area. These areas may be close together or far apart, and they usually wander over the surface in a manner determined by local external conditions. The tendency for a metal to dissolve and force deposition of hydrogen on a cathode is considerable, but the reaction proceeds only when hydrogen escapes from the cathode surface. The hydrogen may escape as a gas, but this rarely takes place in brines except when they are acid. The usual way is for the hydrogen to react with oxygen in solution and form water. Thus, corrosion of iron in the absence of acidity, is dependent upon the presence of oxygen dissolved in water or brine.

Both, calcium chloride brine and sodium chloride brine, are corrosive to most metals. The latter is somewhat more corrosive than the former, especially to zinc. The corrosiveness is increased by dilution, air, acid reaction, excessive alkalinity, and the presence of ammonia in the brine. Addition to the brine of certain corrosion protective materials is of some assistance in diminishing its corrosiveness.

Effect of Strength of Brine on Corrosiveness.—Strong brines are less corrosive than weak brines. Whiteman and co-workers[3] found that the solubility of oxygen is less in strong brines and that corrosiveness in brines is about in direct proportion to solubility of oxygen. As stated earlier in this chapter, for creamery work, brine with a specific gravity of 1.17 to 1.18 is most suitable. This strength should be maintained. A dependable means of guarding against corrosion due to weak brine, lies in weekly tests for density and immediate correction of strength by reinforcing with more salt, as found necessary.

Effect of Air on Corrosiveness of Brine.—Air in brine intensifies its corrosiveness. Oxygen is one of the essential elements of corrosion, and the carbon dioxide absorbed from the air tends in the direction of acidifying the brine. It is important, therefore, that the brine be protected against avoidable exposure to air. To this effect the splashing of the return brine should be prevented by extending the discharge end of the return line

below the surface of the brine in the brine tank. It is helpful further to seal the brine tank as completely as possible, such as by providing it with a tight cover and stuffing all openings around pipes. Covering the surface of the brine with a light oil is suggested by some as an additional protection. For similar reasons violent agitation that causes turbulent waves on the surface in the brine tank, increases the corrosiveness of the brine.

Effect of Acidity on Corrosiveness of Brine.—Brine on the acid side of the neutral point is much more corrosive than brine that is slightly alkaline. Acid solutions, by causing evolution of hydrogen, and by dissolving protective coatings on the metal surface, accelerate corrosive action. Alkaline solutions retard corrosion of iron and steel by building up protective films. Whiteman and co-workers[3] found the corrosion rate of iron and steel to decrease as alkalinity increased, but that at high alkalinities marked pitting occurred, the pitting effect being more severe in sodium than in calcium brine. Alkaline solutions were found corrosive to zinc, because they dissolve the protective coating of zinc rust and evolve hydrogen. Zinc samples in strongly alkaline solution pitted intensely.

For minimum corrosiveness, brine should always be kept on the alkaline side of the neutral point. It should turn phenolphthalein a light pink. This corresponds to a pH of 8.3 to 8.5. In the case of brine containing sodium dichromate, "neutralization" should be carried to a pH of 9.0 to 9.5, i.e., high enough to yield a definite pink (see also "Effect of Chromate on Corrosiveness of Brine" later).

On account of unavoidable absorption of some carbon dioxide from the air in the course of its daily circulation, brine even if slightly alkaline when made up, gradually switches from the alkaline to the acid side. It, therefore, needs checking at regular intervals and its reaction should be corrected promptly when no longer alkaline. Likewise, at the time a new charge of brine is prepared, a small amount of alkali in the form of sodium hydroxide (preferably 76% flake caustic soda), should be added. About 5 pounds of caustic soda per 1,000 gallons of brine is usually sufficient. For creamery purposes, a simple way of testing the brine for reaction is to add a few drops of phenolphthalein indicator to a small sample of the brine. If it remains colorless, it is too near the acid side and needs the addition of caustic

soda. If it turns pink, no correction is needed. A second test should be made after the neutralized brine has circulated through the system. If no pink color appears, the addition of caustic soda should be repeated.

Before adding it to the brine, the caustic soda should be dissolved in a small amount of water and the solution poured into the brine tank. In the case of calcium brine, however, there is danger of the formation of a heavy white precipitate of calcium hydroxide. In order to avoid this, the soda should be diluted at the rate of about 5 pounds caustic soda per 10 gallons of water and the solution must be added to the brine while in circulation. It should be added gradually and in such a manner as to distribute it quickly over a large amount of brine. Fresh calcium chloride brine is slightly alkaline and, therefore, usually requires no alkali at the time it is made up and until it has circulated for some time.

Effect of Ammonia in Brine on Corrosiveness.—The presence of ammonia increases the corrosiveness of brine. This is especially true with reference to copper and zinc. Brine containing ammonia is destructive to the copper coils in the vats and to copper tubes in the surface cooler and internal tube cooler. It was definitely shown by Hunziker, Cordes and Willihnganz[4] that, in the absence of chromate, ammonia causes the brine to be highly corrosive to copper, and that the intensity of copper corrosion increases rapidly and proportionately with an increase in ammonia content of the brine, from 0 to 1,000 p.p.m. Ammonia in alkaline brine is not damaging to iron. In acid brine, ammonium chloride is formed and this is more corrosive to most metals than the hydroxide.

The brine should be tested for ammonia at regular intervals. While large amounts of ammonia are readily detected by the odor and by the high alkalinity of the brine, amounts sufficiently small to escape such detection may still do much damage. The use of caustic soda for neutralizing the brine, eliminates the customary test papers, as a means to detect the presence of ammonia in the brine. However, even very small contents of ammonia, both in the brine and in the condenser water, may readily be detected by treating about one-third test tube full of brine with 1 c.c. of Nessler reagent. For calcium chloride brine the reagent must be floated on the surface of the brine in the test tube. A brown precipitate at the junction of the two liquids indicates

ammonia present. A white precipitate indicates absence of ammonia. The test tube should not be shaken, as the results then are misleading. When testing salt brine no special precaution is required. A brown precipitate or a brown color, upon mixing the Nessler reagent with the salt brine, indicates ammonia. Condenser water is tested in the same manner as salt brine.

Ammonia leaks in the expansion coils are detected by the use of moistened ammonia test paper (phenolphthalein paper), or by means of a burning sulphur stick or thread. If ammonia escapes the paper turns pink, and the sulphur fumes are white. Ammonia leaks most frequently occur in welds and around fittings in the header of the expansion coils, and especially in the upper portions of the coil sections, where corrosion is intensified in the presence of air. In the case of ammonia in the brine, it is, therefore, advisable to start the search for leaks by lowering the brine level just enough to test the upper portions of the coil sections for leaks. If no leaks are discovered by this initial search, then it may be necessary to empty the brine tank and test all parts of each section for leaks.

In the absence of test paper or sulphur sticks, the leaks may also be detected by observing the places where gas bubbles escape from the coils. By stopping the agitator and brine pump long enough to let the brine settle, the brine should clear up sufficiently to see the gas bubbles rise from the leaks, with the compressor operating. In this case it will be necessary to draw brine off to different levels, to determine the presence of leaks in the lower coil sections.

For repairing the leaks, the ammonia is pumped out of the defective sections and they are disconnected for making the repairs. When all the leaks have been repaired, and before the brine tank is refilled with brine, the entire unit should be tested to make sure of the complete absence of ammonia leaks. This is usually done by shutting off all ammonia from the brine tank and pumping air into the expansion coils through the low pressure side, building up a pressure of about 150 pounds. Before starting to pump air, any water that may be in the coils should be let out, as water in the line would blow out the compressor head.

After the air pressure has been built up, the compressor is stopped to observe the pressure-holding efficiency of the system. Absence of loss of gauge pressure obviously indicates complete

freedom from coil leaks. If the system loses gauge pressure, it is apparent that the coils are not completely tight and that further repairs are necessary. The leaks may then be located by going over all parts with a candle, or soap suds may be brushed over the entire surface of the coils, and soap bubbles will appear at the leaks. For obvious reasons, the installation of new expansion coils in the brine tank should also be accompanied by a thorough test for absence of leaks before filling the brine tank with brine.

Removal of Ammonia from Brine.—While the ammonia contained in the brine can be driven off by heating the brine to near the boiling point, this procedure is too cumbersome to justify it. In the case of a moderate amount of ammonia (up to about 100 p.p.m.) in the brine, and if the brine is in satisfactory condition as to density and reaction, it may be used without causing serious corrosion, by the addition to it of a small amount of sodium dichromate, as described later under "Effect of Sodium Dichromate on Corrosiveness of Brine." When heavily contaminated with ammonia, the brine should be rejected and replaced by a new charge.

Corrosion-Protective Substances.—Efforts to render brine non-corrosive have led to the addition to brine of so-called protective agents or substances such as sulphites, phosphates, silicates, chromates, etc. The sulphites have the effect of binding the oxygen, thereby rendering it unavailable for reactions causing corrosion. Sulphites have proved effective in preventing corrosion, but are objectionable because their presence in brine causes the formation of sulphate scale which crusts and insulates the brine-circulating equipment. The phosphates, silicates and chromates have the effect of covering the metal surface with a protective film. Of these sodium dichromate has been found most effective.

The corrosion-protection of sodium dichromate is increased in the presence of caustic soda. Chromates and dichromates in slightly alkaline brine have proven valuable corrosion retarders, especially for iron and steel, tin and copper, and to a lesser extent for zinc. The work of Hunziker and co-workers[5] further shows that 0.273% chromate in brine, with a pH of 9.0 to 9.5 protects copper against corrosion from ammonia, even in the

case of amounts of ammonia up to 1000 p.p.m. For calcium chloride brine 0.171% chromate is sufficient.

The chromate is usually added in the form of commercial sodium dichromate ($Na_2Cr_2O_7$) because of its lower cost. In the presence of caustic soda in the brine, the dichromate changes to sodium chromate (Na_2CrO_4). This reaction dissipates the alkalinity of the brine and may change its reaction to the acid side. Since the protection against corrosion on the part of the chromate requires an alkaline condition, enough caustic soda need be added to make the brine definitely alkaline (pink) to phenolphthalein.

Chromate compounds have recognized toxic properties; they are poisonous. They must, therefore, be kept out of food products. Some individuals condemn their use in brine altogether on the ground, that occasionally the milk or cream cooler may not be tight, causing leakage of brine into the dairy product while it is being cooled. Others hold that chromate should be used in closed brine systems only. The correctness of the spirit and intent of these precautions is obviously timely and unassailable. The dairy product must be kept free from contamination with chromate. The fear that is prompting such abstinence, however, is largely theoretical. The possibility of injurious infection of milk, cream or butter with chromate from creamery brine, is exceedingly remote and improbable. Chromate-treated brine has, in fact, been in general use in creameries with open or closed brine systems, for years, and to the knowledge of the author there is not a single case of chromate poisoning from dairy products on record. Moreover, it is very improbable that there have ever occurred unrecorded instances of injury to the health of the consumer resulting from the treatment of creamery brine with chromate, nor have the health authorities, federal, state or municipal, deemed it necessary to provide legislative regulations prohibiting the chromate-treatment of creamery brine.

Refrigerant Media Other Than Brine.—In efforts to overcome or eliminate the corrosive tendencies that are inherent in the brine system, consideration has been given to other refrigerant media. Of these alcohol has been given preference and is actually in successful use in the place of brine, in numerous refrigeration installations.

Alcohol has some distinct advantages. Its non-corrosiveness eliminates the ever-recurring necessity of neutralization and of the addition of corrosion-preventives. Its use rids the factory of corroded and leaky brine tanks, ammonia coils, vat coils, vat nipples, and pipe lines carrying the refrigerant. Its low specific gravity lessens the load of circulating pumps. Its low freezing point does away with the danger of crystallization and freezing. Its cost is sufficiently moderate to justify its use. At the relatively low temperature (usually below 32° F.) of the circulating brine in the creamery, the danger of alcohol evaporation and objectionable odors would be negligible, suggesting the suitability of alcohol as refrigerant for creamery use.

COOLING BY DIRECT EXPANSION

Advantages.—The advantages of direct expansion in the creamery, in the place of using brine as the refrigerant, are obvious. The brine system involves a very considerable initial investment, consisting principally of brine tank with agitator, and expansion coils, brine circulating pump and insulated piping of large size to and from cold room and cream coolers. Because of the corrosiveness of brine the cost of upkeep is relatively high. Operation of this intermediate set of equipment for heat transfer adds to the power cost, and the brine and its continuous need of reinforcement to maintain its desired strength, further increase the operating cost. Elimination of the brine system, therefore, makes possible a very material reduction in plant operating cost, and in space needed for equipment.

The principal disadvantage of the direct expansion system for cream cooling is that this system requires a larger compressor, due to the heavy demand on it at the time of operation of the cream cooler. This is the case in spite of the fact that cooling by direct expansion makes possible operation to more nearly the full capacity of the compressor.

Direct Expansion in Cold Room.—The use of direct expansion in the creamery cold rooms is not new. Its advantages in expediting the cooling of these rooms and in attaining lower temperatures are fully recognized. Its disadvantage here lies in the fact that, in creameries that operate the compressor during working hours only, the cold room is without refrigeration during the night, while in the case of the brine system, the cold

stored up in the brine during the day provides the refrigerant for the cold rooms after the compressor ceases to operate. This disadvantage may be, and is in fact, largely eliminated in the case of direct expansion by the installation in the cold rooms of calcium chloride drums, which serve as reservoirs of cold.

Direct Expansion Surface Coolers.—The direct expansion surface cooler usually has one or two sections of water cooling, followed by one section of direct expansion ammonia pipes. The varying flow and temperature of the milk or cream to be cooled cause violent changes in the boiling point of the ammonia, that

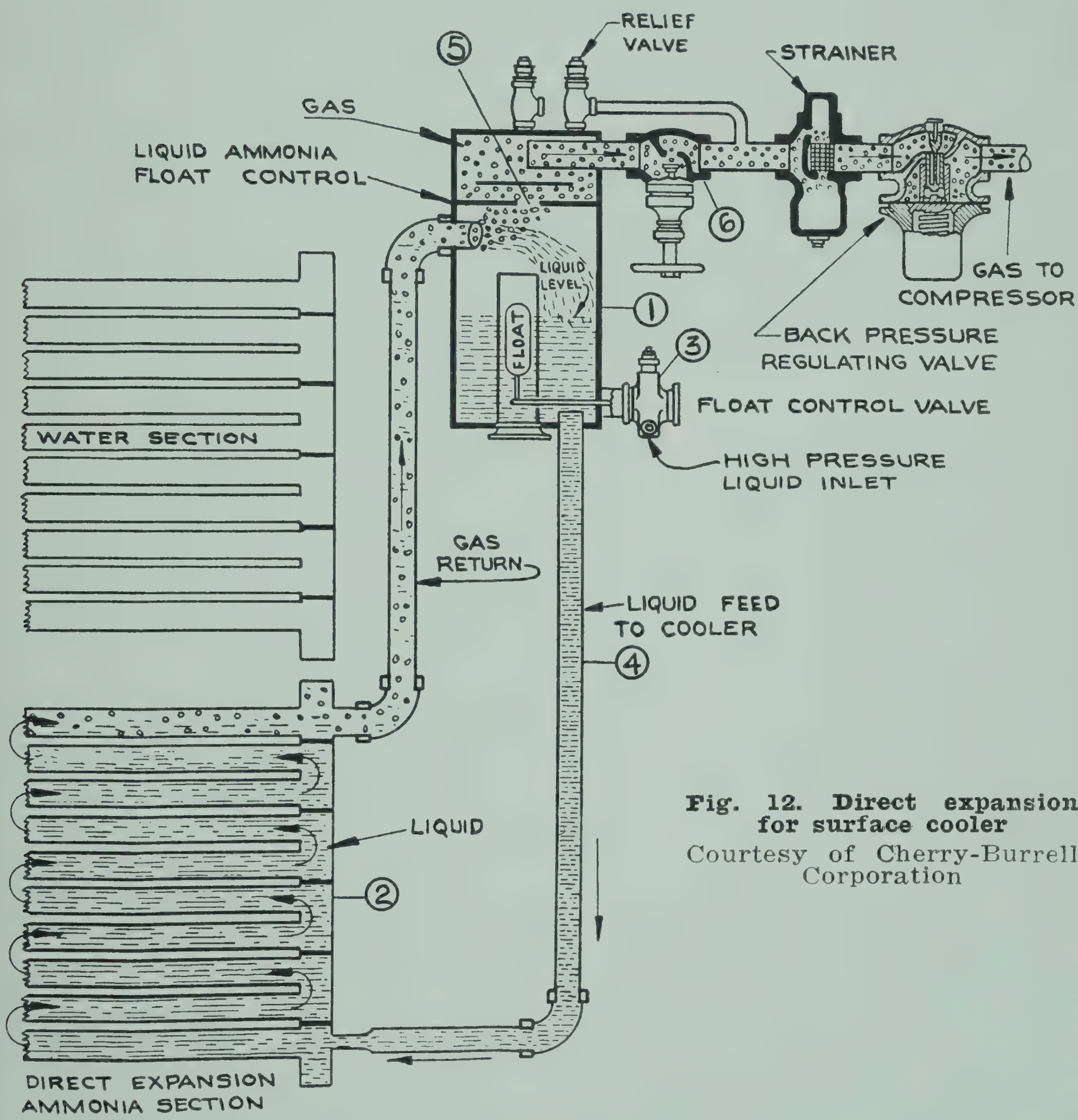


Fig. 12. Direct expansion for surface cooler
Courtesy of Cherry-Burrell Corporation

affect the flow-back conditions of liquid ammonia, tending to decrease the active refrigerating area of the cooler tubes, to increase the power requirements of the compressor for the

operating suction pressure, and to cause excessive wear and tear on the compressor.

These difficulties have been successfully overcome by the installation of a float valve in the receiver, that regulates the supply of ammonia liquor, to take care of the fluctuating load on the cooler. The mechanism of ammonia circulation in the surface cooler is illustrated in Fig. 12. In the diagram shown the receiver or accumulator (1) is elevated and the ammonia circulates through the direct expansion cooler section (2) by gravity.

The liquid ammonia from the compressor enters the accumulator near the bottom, through a float control valve (3), which maintains a constant level of liquid ammonia. From the accumulator the ammonia flows through liquid feed line (4) to the bottom of the surface cooler (2), in which it circulates as indicated by arrows shown in the drawing, vaporizing as it takes up heat from the cooling cream. The ammonia gas and entrained liquid leave the direct expansion cooler section at the top, returning to the accumulator where the gas escapes through port (5), while the liquid collects in the accumulator for recirculation.

The accumulator thus acts as a reservoir in which a constant liquid level is maintained by the float. It also provides the means of automatically separating out the flash gas resulting from the reduced pressure upon expansion. The accumulator likewise separates out any entrained ammonia liquor coming back from the evaporator (surface cooler), preventing it from returning to the compressor. A further safeguard against freezing on the cooler, due to fluctuating loads, is provided by a back pressure regulating valve (not shown in drawing), in the suction line to the compressor, thereby maintaining a constant temperature of ammonia in the cooler.

At the conclusion of the cooling operation, the liquid ammonia from the compressor is shut off, while valve (6) in the return line of the gas to the compressor is left open until the cooler is practically emptied of ammonia. Thus, the cleaning and sterilizing of the cooler can proceed immediately, without danger of damage and without delay. Furthermore, the heat sterilizing treatment is more efficient than in the case of brine coolers, because there is no cold refrigerant such as brine in the tubes, and there is no loss of heat, nor waste of cold.

In the case of installation with the receiver located below the cream cooler, the liquid ammonia is circulated through the cooler by means of a pump, and a by-pass from cooler back to receiver may serve to drain the ammonia from the cooler during intervals when no milk or cream flows over the cooler, and for emptying the cooler at the conclusion of the run.

The usual range of gauge or suction pressure at which the direct expansion section of milk and cream coolers are operated, lies within the limits of approximately 35 to 45 lbs. At 35 lbs. pressure the boiling temperature of the ammonia is about 21° F. At a gauge pressure of 44.72 lbs. it boils at 30° F. The boiling points of ammonia at different gauge pressures are given in Table 7.

Table 7.—Relation of Gauge Pressures to Boiling Temperature of Ammonia

Boiling Temper-ature ° F.	Pressure at Sea Level		Boiling Temper-ature ° F.	Pressure at Sea Level	
	Absolute Pressure* Lbs. per Sq. In.	Gauge Pressure Lbs.		Absolute Pressure* Lbs. per Sq. In.	Gauge Pressure Lbs.
0	30.42	15.72	40	73.72	59.02
5	34.28	19.58	45	80.95	66.25
10	38.51	23.81	50	89.19	74.49
15	43.15	28.45	55	98.05	83.35
20	48.21	33.51	60	107.6	92.9
25	53.73	39.03	65	117.8	103.1
30	59.74	45.04	70	128.8	114.1
35	66.26	51.56	75	140.5	125.8

*U.S.B. Standards. Lange's Handbook of Chemistry, 1937.

Direct expansion cooling of milk and cream is applicable for surface coolers and internal tube coolers. In the case of coil vats, in which the refrigerant circulates through the revolving helical coil, the direct expansion system has not as yet been found practical. Its use in the creamery, therefore, presupposes the use of the surface cooler or internal tube cooler. However, the simplicity, convenience, efficiency and economy of cooling by the direct expansion system are such, as to justify installation and use of the surface cooler or the internal tube cooler in plants that pasteurize their cream in coil vats, as well as in flash pasteurizing plants.

Insulation of Ammonia, Brine, Steam and Water Pipes.—Efficient insulation of heat and cold conducting pipe lines saves fuel and power, and constitutes a sizable factor in factory operating economy.

Suitable insulating covering, properly put on, is needed for all ammonia return lines, brine pipes, steam pipes, and it is desirable for hot and cold water lines. It is usually most economical over a period of time, to consult the advice and secure the assistance of a reliable insulation material firm regarding choice of insulation for each type of pipe line, and regarding the most efficient manner of covering them, such as will insure permanency of covering, minimum sweating and frosting, and maximum insulating efficiency.

WATER-TEMPERING SYSTEM

The creamery has need of a dependable and practical system for the suitable tempering of the water used for washing the butter. The temperature of the wash water is sufficiently important to provide definite facilities for this purpose. These facilities should be of a nature that will yield water cold enough for every condition of the butter and that will make the needed supply of this cold water immediately available during all hours of the working day.

In addition, these facilities should include a convenient system of tempering (raising the temperature of) this cold water to any temperature best suited for each individual churning, and of conveying the tempered water into the churns with minimum expenditure of labor and time.

Methods of Cooling and Tempering the Water.—The methods that are in use for this purpose vary with different creameries. Thus, the cooling of the water may be done by storing it in a cooling tank usually called sweet water tank; or by holding the water in a battery of pipe sections installed in the cold room; or by passing the water through an internal tube cooler. The tempering of the chilled water for individual churnings may be done in a heating tank usually known as the tempering tank; or by means of a steam jet or hot water connection in the water line over the churns; or by such temperature control when cooling in the internal tube cooler, as to have the outflowing water at the desired temperature for individual churnings.

The Sweet Water Tank.—The sweet water tank provides a convenient and semi-automatic supply of water at a temperature low enough for butter of any condition. It is preferably located on the floor above the factory room to permit the water to flow to the tempering tank or churns by gravity. It is equipped with either brine pipes or direct expansion coils. Galvanized iron pipes are preferred to black iron pipes for this purpose. The regulation of its water supply is simplified by the installation of a float valve. By this means a constant water level is maintained, and as fast as the cooled water is withdrawn for use, fresh water automatically enters. Its capacity must obviously vary with the daily water requirements for washing the butter. In general, it has been found desirable to have this tank large enough for one day's supply of butter wash water. The sweet water tank should be provided with a suitable cover to protect the water against defilement with impurities from the air.

The most serious objection to the sweet water tank lies in its potential menace as a source of damaging bacterial contamination of the water. The prolonged storage of water, in the absence of frequent emptying and cleaning of the tank, tends to cause a stagnant condition, and the development of a slimy coating on the walls of the tank and on the coils, and possibly the appearance of mold spots, conditions that inevitably jeopardize the microbiological purity of the water.

This condition can be prevented, however, by systematic cleaning of the tank, such as by emptying it at regular intervals (once a month), thoroughly scrubbing its inside and the surface of the coils, with a stiff brush and water containing washing powder, and flushing it out with hot water. In case of mold spots, a final treatment with a strong chlorine solution, or of rubbing a paste of bleaching powder directly into the water side of the walls of the tank and leaving it there for several hours, followed by thorough flushing with water, is recommended.

Pipe Coolers in Cold Room.—For cooling the wash water in pipe sections installed in the cold room, the battery of pipes should have sufficient capacity to hold the water required for most of the churnings of one day, otherwise the tendency is for the water not being left in the pipes long enough for the desired chilling. Two inch galvanized iron pipes are generally used for this purpose.

Internal Tube Cooler.—The internal tube cooler, with adjustable automatic temperature control, cooling the water to, and delivering it at the desired temperature, has the advantage of both cooling and tempering the water. It eliminates the need of other equipment, is capable of yielding water at any desired temperature, and practically eliminates all danger of water contamination. It necessitates, however, operation of this cooler for the water supply of each individual churning.

Tempering the Cooled Water.—For tempering the cooled water, i.e., adjusting its temperature upward for individual churnings, the use of a tempering tank is by far the most dependable arrangement. It insures a uniform temperature of the entire water supply for each churning. This tank need not be large. A capacity sufficient to provide the butter wash water for one churning (about 200 gals.) is sufficient for creameries with three to four churns. A copper tank tinned on the inside, is very suitable for this purpose. The simplest means of tempering or heating the water is by live steam, using a noiseless steam jet water heater, such as the Pemberthy. The tempering tank should be equipped with a readily readable index thermometer. Its outlet should be screened with a fine wire mesh sleeve to strain out any sediment or scale present in the water. This tank should be sufficiently elevated to service the churns by gravity. The tempering tank has the additional advantage of supplying dependably hot water for washing and scalding the churns. It is harmless from the sanitary standpoint, as it is emptied and refilled many times during the day, and its final use for boiling hot water at the end of the daily manufacturing routine insures its satisfactory condition bacteriologically.

Tempering the chilled water for washing the butter by means of a steam jet installed in the water line over the churns, is the simplest arrangement, but also the least dependable as to uniformity of the temperature of the water that reaches the butter in the churn. It has the additional drawback that in case of a leaky or incompletely closed valve in the steam connections, the first or last water to the churn may have so high a temperature as to jeopardize both body and uniformity of color of the butter.

In some plants with ample cream vat capacity, one of the cream coil vats is reserved for the cooling and tempering of the butter wash water. Where such a vat is automatically available,

its use for this purpose will take care of every temperature adjustment desired. The initial cost of coil vats, however, generally does not justify its purchase for use as a tempering tank only.

Arrangements for Handling the Butter Wash Water at the Churn.—The facilities provided for conveying the properly tempered water to the churn, vary from portable tanks on low wheels from which the water is laboriously bailed into the churn with a bucket, or tanks mounted on wheel trucks sufficiently high for the outlet gate of the tank to clear the bottom of the churn door frame, or tanks operated on overhead conveyors; to piping the water from the tempering tank direct to the sanitary cream line installed over the top of the churns, with suitable down-spouts to each churn. The pipe line system is mechanically obviously the most convenient and usually the least time-consuming.

REFERENCES

1. THE BABCOCK AND WILSON CO., Steam, Its Generation and Use, 36th ed., (1923).
2. SER and JOULES, quoted by Hausbrand, Verdampfen, Kondensieren u. Kühlen, (1918).
3. WHITEMAN, W. G., CHAPPELL, E. L., and ROBERTS, J. K., Refrig. Engineer *12*, 158, (1925).
4. HUNZIKER, O. F., CORDES, W. A., and WILLIHNGANZ, R. A., Blue Valley Res. Labs. (not publ.), (1933).
5. HUNZIKER, O. F., CORDES, W. A., and NISSEN, B. H., J. D. Sc. XII, *3*, 252, (1929).

CHAPTER IV

CREAMERY EQUIPMENT

MATERIAL OF CONSTRUCTION, MECHANICAL CARE AND USE

WOOD IN CREAMERY EQUIPMENT

In the early days of buttermaking on the farm, most of the equipment used was of wooden construction. With the development of the factory system of butter-manufacture the trend has been progressively toward metal construction. Today wooden construction is confined largely to such creamery equipment as churns, butter trucks, machines and tools for the packing and cutting of butter, buttermilk tanks, wash tanks, tanks used for the treatment of parchment liners and wrappers, and the sweet water tank.

Even in the case of the equipment enumerated above, we find many exceptions where wood has been more or less completely replaced by metal. Thus, the all-metal, rolless, aluminum churn of the Jensen Creamery Machinery Co. of Bloomfield, N. J., has been in successful use for a number of years and has demonstrated its sanitary superiority over the wooden churn. In the case of butter printing equipment, the wooden Friday cubes have been supplanted in some creameries by the more expensive, but far more sanitary and more durable stainless steel cubes, and in the continuous butter cutting and molding machines, the sanitary status of hoppers, hopper boxes and Archimedean screws, has been greatly improved by constructing these parts of suitable metal in the place of wood. For wash tanks and tanks used for the treatment of parchment liners and wrappers, soap stone construction has proved more suitable than wood. In the case of large tanks, such as the sweet water tank and buttermilk tank, the elimination of wood would be desirable, but the relatively high cost of suitable material other than wood has retarded the abandonment of wood in this auxiliary type of equipment.

Advantages of Wood in Creamery Equipment.—The principal reasons for the persistence of preference for wood over

metal in the construction of certain types of creamery equipment lie mainly in the lesser cost, lower heat conductivity and ability to handle butter without sticking to the surface of contact.

That the difference in initial cost of equipment between wood and a suitable metal constitutes an impressive factor in favor of wood is undeniable. This is true of both material cost and cost of fabrication. For a convincing illustration of this fact the simple Friday cube, 12½″x13⅞″x15⅝″, may be cited. The wooden cube is available at approximately $8.00, while the stainless steel cube costs about $27.00. Especially in the case of the small creamery with limited financial resources, this difference in initial cost may serve as the deciding factor in favor of wood, although experience has demonstrated that over a period of years, the metal equipment usually proves the more economical, because of longer life and the practical elimination of expense of upkeep.

In addition to its cheapness, wood has certain physical properties that render it highly suitable mechanically for equipment used in the handling of butter. Because of its low heat conductivity and its stickiness-preventing porosity, wood has no equal for the construction of such equipment as churns, and machines and tools used for packing butter. More recent efforts have demonstrated, however, that the surface of certain cast metals is sufficiently porous, or can be made so by proper treatment, to practically eliminate the tendency of the butter to stick to the metal surface.

Objections to Wood in Creamery Equipment.—Unfortunately, the very properties, low heat conductivity and porosity, that render wood outstandingly suitable mechanically, are associated with properties that are highly objectionable for sanitary reasons. The pores of wood tend to accumulate remnants of perishable milk constituents and provide potential breeding places for micro-organisms that contaminate the butter, and the low heat conductivity hinders the effectiveness of heat sterilization. Furthermore, these pores give the wood properties similar to those of a sponge. They absorb moisture and free water, causing swelling and warping. This in turn tends to open wooden joints and to expose cracks that fill with milk constituents which are difficult to remove and which

provide food for bacterial putrefaction. In short, wood in creamery equipment is fundamentally a potential enemy of sanitation, and may readily become a virile source of damaging contamination of butter and a menace to quality.

The Mechanism of Damaging Contamination from Wooden Creamery Equipment.—In order to tangibly visualize the ease with which wood becomes contaminated with germ life, the difficulty of eliminating such contamination, and the effort required to keep wooden creamery equipment in sanitary condition, it appears helpful to consider the movement of the food supply of a growing tree. The living tree depends for its food metabolism on substances taken from the ground and transported upward through the trunk, and on elements taken from the air that are carried from the crown down to the roots.

To make this movement of food supply possible, the structure of wood constitutes a system of narrow canals or hollow tubes running lengthwise with the grain, through which these substances travel up and down in liquid form. These hollow spaces or tubes are of very small diameter, mostly invisible to the naked eye, but in relation to the size of bacteria they are very large, as illustrated in Figure 13, originally designed by Bieri.[1] Because of the great length of these hollow canals bacteria can penetrate into the wood to a considerable depth,

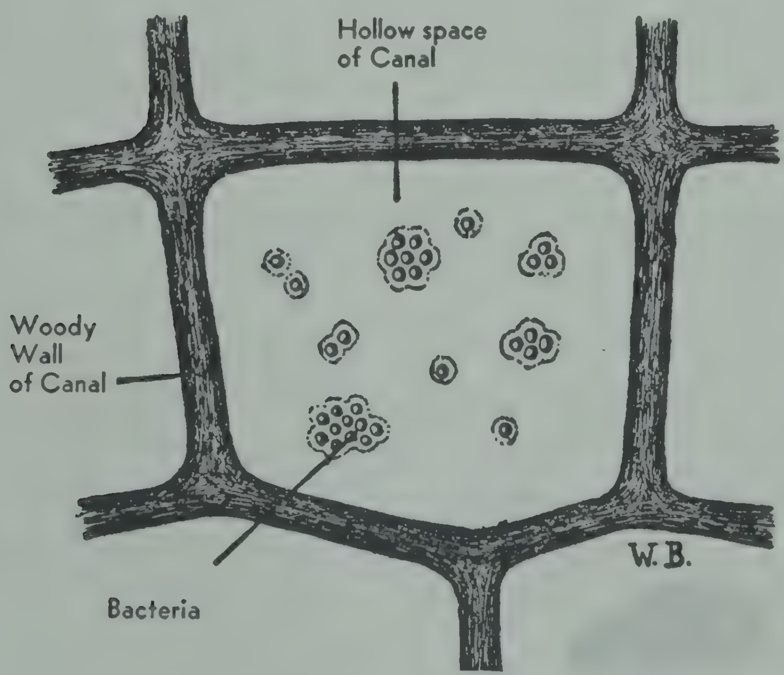


Fig. 13. Cross section of a growing Red Pine tree (Pinus resinosa), showing one of the multitude of canals through which sap travels, and relative size of bacteria (magnified X 500)

where they are protected against the usual means employed for germ destruction, such as heat or chemical sterilizers.

In addition, this structure lends the wood its sensitiveness to changes in temperature and humidity, making it swell and

warp in the presence of water and of heat, and shrink when dry and when cold. In the routine operation of creamery equipment these properties of wood cause wooden joints to successively open and close, admitting remnants of milk, cream, wash water and butter, locking them up and concealing them in the closed cracks, from which they are not removed by the routine of washing, and where they are not effectively reached by the usual agencies available for sterilization. These hidden milk remnants then undergo putrefaction and serve as a continuous source of damaging contamination of the dairy product with both, the products of decomposition, and the germ life causing it.

CHURNS

Wood in Churns and Butter Workers.—Soft woods, such as yellow poplar, hemlock, ash, soft maple, white pine, basswood, cedar, and the like, are not particularly suitable for churn construction, because their rapid annual growth yields thick ring layers with large thin-walled cells, producing a wood of limited firmness and that is especially favorable to bacterial penetration. Some of the soft woods also have a pronounced tendency to splinter, sliver, or crack, and most of them lack prolonged resistance to decay upon continued exposure to dampness.

The choicest woods for churn construction are among the hard wood species, which are relatively very hard, firm and compact, having thick-walled cells with a minimum of intercellular spaces or ducts, they do not readily splinter, sliver or split, and as a whole are fairly resistant to dry rot. Teakwood and mahogany excell in this respect and are given preference in countries where they are naturally available, or can be procured at reasonable cost. Other suitable woods are cypress, beech, oak, fir and redwood.

The earlier factory churns in the United States were made of cypress for the barrel and poplar for the worker rolls. While the cypress then available was first growth timber and of high quality, later on second growth cypress had to be resorted to and proved unsatisfactory largely on account of the ease with which it developed dry rot. Today the predominating wood used for churn barrels in this country is Douglas fir, and for worker rolls California redwood. The straight grain Douglas

fir has proved much superior to the second growth quality of cypress, particularly relative to its resistance to dry rot. California redwood likewise is much more suitable for worker rolls than poplar. The redwood has a close grain, is firm and

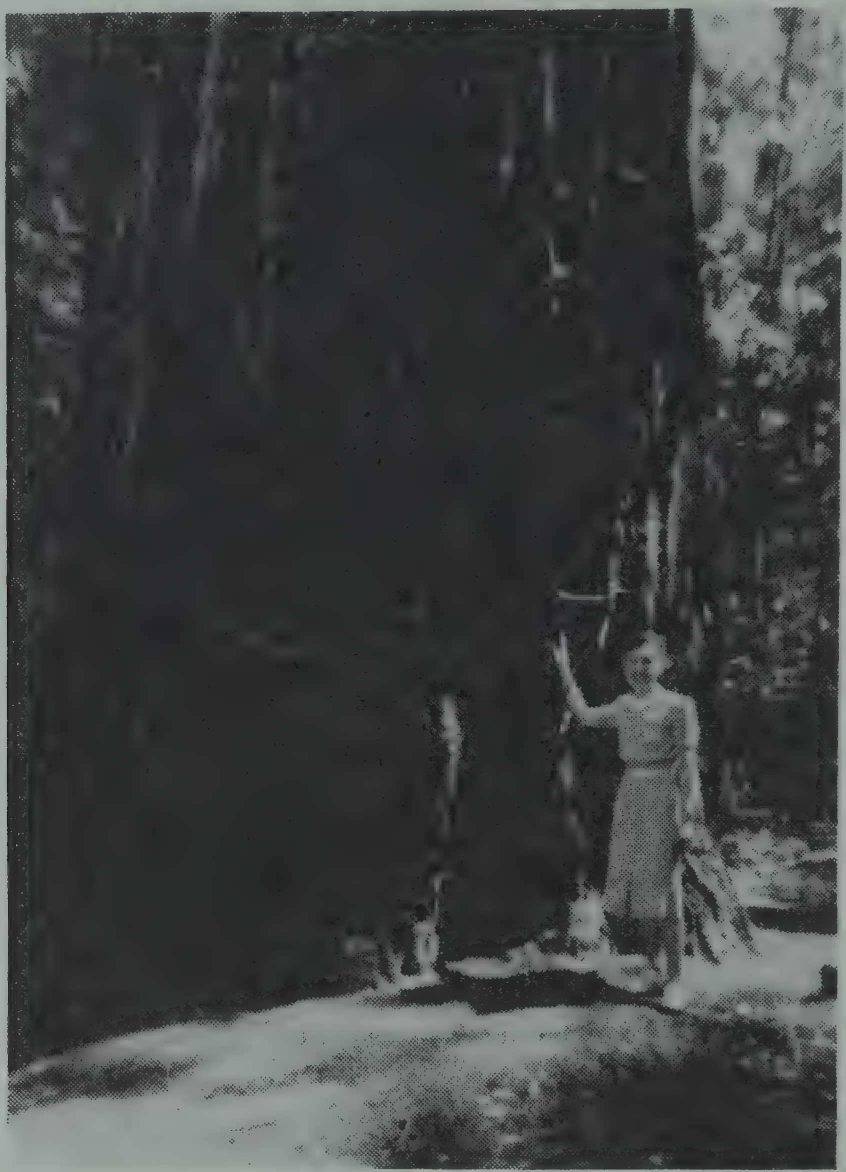
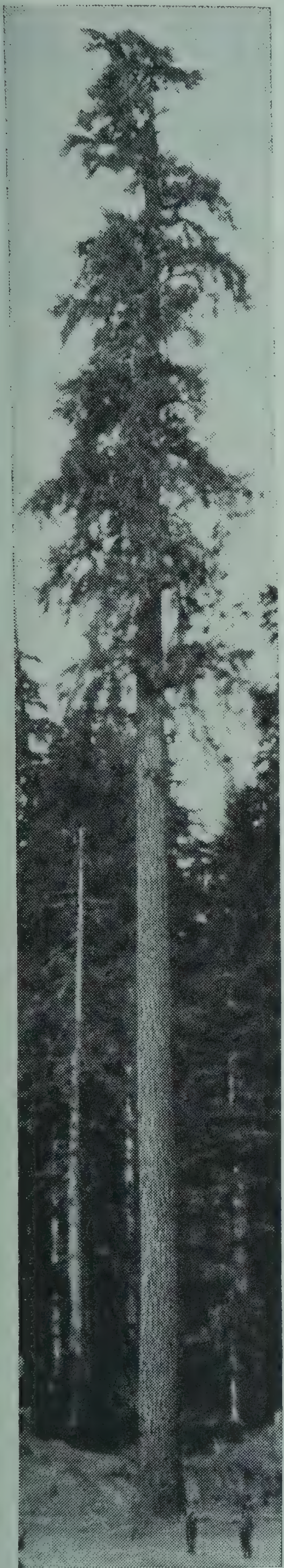


Fig. 14. Among the giant Redwoods (Sequoia sempervirens) of California

free from cracking, wears well and stands up well in the presence of water and dampness, while poplar is relatively soft, wears rather fast, and has a tendency to crack. Both redwood and Douglas fir are native woods of the Pacific Coast.

Sanitary Construction of Churns.—The workmanship of the completely assembled churn barrel should be of such quality as to preclude the presence of openings and cracks between staves and between ends and staves. Cleats and inlays of wood are enemies of sanitation. They inevitably swell, warp and open cracks that become sources of damaging contamination. They, therefore, should be eliminated. The churn shelves should not be installed tight against the staves. The shelf



should preferably be a solid stave extending into the churn. If it must be a separate piece of lumber it should set away from the periphery toward the center of the churn sufficiently to eliminate the possibility of the lodging of milk constituents between shelf and staves, and to afford ready cleaning of the space between shelf edge and staves.

For similar reasons the worker rolls should be made of one solid piece of lumber. Even when at rest, rolls of composite construction of multiple pieces of wood will open cracks due to inevitable contraction, expansion and warping. The heavy strain on the worker roll when in operation vastly augments the tendency of wood joints to open up sufficiently to admit milk constituents which decompose between churning days, and this corruption is squeezed out of the apparently sealed cracks, due to the strain and twist on the rolls, continuously feeding the butter of succeeding churnings with putrefactive material and its causative germs. The manufacture, use and toleration of composite worker rolls consisting of multiple pieces of wood bolted together, constitute a deplorable travesty of foresight on the part of the churn manufacturer, of common sense on the part of the user, and of intelligent enforcement of sanitary laws by health authorities. The solid, one-piece worker roll is the only answer for churns with mechanical workers.

In addition the ends of the rolls constitute a constant menace to the sanitary protection of the butter. They are most subject to decay because they lay open the terminals of the longitudinal canals in the

Fig. 15. Douglas Fir (Pseudotsuga tarifolia)
Courtesy of School of Forestry, Oregon State College

structure of the wood, facilitating practically unlimited penetration of dampness, milk constituents and germ life. They are very inaccessible to cleaning, and the squeezing of butter in between end of roll and end of churn during the working process is unavoidable. The menace of this condition is apparent whenever rolls are removed from the churn barrel. It has also been convincingly demonstrated by the experiments of Demeter and Christiansen.[2] In this respect the churn with separate workers moved into the churn on a worker roll carriage is a distinct improvement, and the rolless churn eliminates this objection altogether.

Metal Parts in Churn Drum.—In sanitary churn construction all iron parts in the wood inside of the churn must be eliminated. This refers to such parts as hidden nails and screws, bolts and bolt heads, shelf brackets, worker roll caps, etc. Contact of butter with iron, even during its short exposure in the churn, is detrimental to flavor and keeping quality. In addition, iron in the wood on the inside of the churn is exceedingly destructive to the wood, causing profuse black discoloration and rapid decay that begins in the immediate vicinity of the iron and extends longitudinally with the grain of the wood over wide areas. While galvanizing and especially tinning (hot dipped) minimizes the menace to quality at least for a limited time, and while concealed bolt heads eliminate metal contact with butter, these precautions are meaningless relative to the protection of the wood.

The work of Hunziker and Behlmer[3] has demonstrated conclusively that the presence of iron parts in the churn, whether concealed or exposed, is one of the chief causes of wood decay of the churn barrel, suggesting the probability that many cases of so-called dry rot are in reality decay resulting from contact with iron parts. Their study further showed that the replacement of iron parts with stainless steel, eliminates decay from this source and prolongs the life of the churn. Stainless steel in direct contact with butter likewise has no damaging effect on the butter.

Sight Glasses in Churn Drum.—The sight glasses or spy glasses in the churn drum should be constructed of pyrex glass, seated with sufficient allowance for heat expansion to prevent cracking when heat sterilizing the churn. Cracked spy glasses

may cause the incorporation of glass chips in the butter, which become practically invisible, once they have been worked into the butter, and the removal of which, in case of knowledge of their presence, would require the melting of the entire churning. The presence of glass in butter not only jeopardizes the safety of the consumer, but may lead to embarrassing and costly law suits.

Gaskets in Churn Doors.—The gasket for the churn door frame should be of such material, quality and mechanical fit, that it will permanently stay in place, will provide a dependably tight seal, and will resist disintegration due to wear and heat treatment. Leaky gaskets result in costly losses due to leakage of cream. Crumbling or tearing of the gasket may cause the incorporation in butter of objectionable extraneous matter in the form of particles resulting from such disintegration dropping unnoticed into the churn. Cork gaskets are prone to crumble. Soft rubber gaskets are sensitive to sterilizing temperatures causing tearing. A high quality rubber fabric appears to best eliminate these objections.

Churn Screens.—When not in actual use the churn should be left with its doors up, open or unhinged, to insure satisfactory air circulation. In order to protect the interior of the churn from contamination with impurities in the air there should be readily available a properly constructed and reasonably durable screen for each churn door. This is preferably made of fine wire mesh, rust-proof screen, securely fastened to a substantial wooden frame that fits properly and snugly into the door frame.

SANITARY CARE OF THE CHURN

Painting the Churn.—For the best preservation of the churn barrel the wood must be allowed to breathe. This is possible only in the presence of open pores on both sides of the wood. Covering the churn barrel with paint closes its pores on the outside and tends to stagnate the wood. The paint usually soon develops blisters due to the vapor pressure caused by the daily heat treatment of the inside of the churn, and frequent repainting is necessary for the sake of appearance. While a new coat of white paint on the churn drum improves the general appearance of the creamery, it is contrary to the fundamentals

of churn sanitation, and the need of frequent repainting is a recurrent considerable expense that is of no benefit to the churn.

Coating the churn barrel with oil or varnish likewise has the effect of closing the pores of the wood. While coatings of these materials do not blister and are much less expensive than paint, the churn is best served by absence of all applied coatings. Its exterior can be kept presentable and clean by thorough washing with hot water (near boiling point) after the day's operations, using some mild alkali washing powder, when needed, to remove grease. The appearance of the churn drum is further improved by painting the metal hoops with paint of suitable color.

Treatment of New Churn.—The wood of the new churn before use is dry. When it is put into service the wetness swells it. This makes necessary the light but sufficient loosening of the hoops, when first used, to allow for this swelling and to guard against warping of staves or bursting of hoops. After this initial swelling, the gradual retightening of the hoops becomes necessary. They should be watched and adjusted to keep them satisfactorily tight at all times. All adjustments of tightening or slackening the hoop bands should be made gradually, giving the bolts a quarter of a turn at a time, as needed. Loose hoops permit spreading of the staves, causing remnants of milk constituents to get permanently lodged in the resulting cracks between staves and at the stave ends, thus developing an insanitary condition of the churn, jeopardizing the quality of the butter, and shortening the life of the churn.

The new churn barrel should be examined, and if there are any mold spots in its interior, which is not infrequently the case, it needs a thorough scrubbing with hot water containing a mild alkali, removing all mold spots, followed by a good scalding with boiling hot water.

As a general practice, the new churn should be given a thorough and prolonged soaking before use, preferably filling the churn about one-half full with water at ordinary temperature, allowing it to soak for a day or two and revolving it at reasonable intervals for about one-half hour. This will assist in swelling the wood gradually, stopping leaks and eliminating wood odors. The churn is then emptied and refilled about half full with hot water (about 180° F.), running it in low gear

about one hour. If used on the same day, the hot rinse should be followed by a cold water rinse (50° F. or lower), revolving the drum in low gear for about half an hour. If not used until the following day, the cold rinse is preferably omitted, and after emptying the drum, the churn is stopped with the door openings facing upward, inserting the churn screens, and opening the buttermilk gate. During the soaking and the hot water rinse, the hoopbands require some attention as indicated above. At the conclusion of the treatment the hoops should be tight.

Daily Washing of the Churn.—The menace of the churn as a potential source of damaging contamination of the butter was emphasized in the foregoing paragraphs. The wooden churn, especially the combined churn and worker, is in fact the most difficult piece of creamery equipment to keep in satisfactory sanitary condition. The necessity of establishing and conscientiously following a definite routine system of treatment before and after daily use, that insures thorough cleaning and efficient germ destruction, is obvious.

Treatment of Churn Before Use.—A churn that has received proper cleaning and sterilizing treatment at the end of the day's operation, and has been allowed to dry quickly, may be expected to be in the best possible sanitary condition the following morning. Yet, comparative bacteriological analyses show a tendency for the butter of the first churning of the day to yield higher counts of bacteria, yeasts and molds, than that of succeeding churnings. This suggests the probability of some bacterial contamination or development in the surface of the wood over night, and it emphasizes the need of sterilizing treatment in the morning before use. The particular treatment will necessarily vary somewhat with facilities and available time. The really important factor for dependable results is that the operator have a definite system of treatment and follow it religiously. The following procedure has been found effective:

Rinse the churn with from 50 to 100 gallons of boiling hot water, revolving the drum in low gear at least five minutes. The water must be real hot, at least 200° F, in order to accomplish the purpose of germ destruction. The churn is then thoroughly chilled by using about 50 gallons of as cold water as possible,

50° F. or below, and revolving the drum in low gear for 15 minutes.

If time or facilities do not permit of the hot rinse, the treatment may be confined to chilling with the cold water to which has been added enough hypochlorite solution to have the water contain approximately 100 p.p.m. chlorine. This requires the addition of from 1.3 to 1.5 pints of 3% chlorine solution to the 50 gallons of cold water.

Treatment of Churn at End of Day's Operations.—The important fundamentals to be accomplished here are: 1.) Elimination of butter adhering to drum and worker rolls by a quick rinse with water warm enough to melt the butter. This rinse should be discarded promptly to prevent the butter oil from soaking into the wood causing oil spots. 2.) Cleaning the churn with hot water containing a mild alkali, such as a mixture of carbonate and bicarbonate of soda, to dissolve remnants of curd and emulsify fat. This requires large volumes of hot water and ample time. Strong alkalies and caustics should be avoided as they destroy the firmness of the wood, making it soft and fuzzy, and leading to stickiness. 3.) Sterilizing the churn with large amounts of as hot water as possible, using ample time. In short, efficient treatment means first quickly eliminating the bulk of butter remnants, followed by rinses of large volumes of water, high temperature and allowing plenty of time for exposure to each large volume, hot water rinse. The following procedure has been found helpful:

1.) Rinse the churn with a small amount (about 30 to 50 gallons) of water at 120° F., give the drum a few revolutions and empty immediately.

2.) Follow this at once with hot water at a temperature of about 160° to 180° F. containing about 2 lbs. of a neutral soda such as Wyandotte cleaner and cleanser, or of sodium Sesquicarbonate, per 100 gallons of water. If soda ash or sal-soda is used, add only one-half the above amount. The volume of this water should be sufficient to fill the churn about one-third full. Revolve the drum in high gear for about 15 minutes, then empty.

3.) For the last rinse use as hot water as possible, preferably 200° F. or above. Use a large volume of this hot water, filling the churn from one-third to one-half full, so that the worker

rolls won't miss the hot water rinse. Revolve in high gear for not less than 15 minutes, then drain through churn doors and leave to drain for five minutes.

4.) Wash exterior of churn with hot water and soap or mild alkali.

5.) Turn drum so that the churn door openings face upward. Insert the churn screens and open the buttermilk gate.

6.) Worker rolls mounted on a separate carriage, such as is the case with the Simplex type of churns, are best left in gear during churn treatment, after which they should be removed, scrubbed with brush and hot water containing a neutral soda or other mild alkali, followed by a thorough hot water rinse. It is good practice to finish the treatment by sprinkling dry salt over the entire surface of the rolls. For the morning treatment the rolls should again be placed in gear while treating the churn.

Churns lying idle need a daily rinse with water at 200° F. to protect the wood from progressive development of molds and other germ life while not in use.

Precautions.—The heating of the water used for churn treatment should be done outside of the churn. Heating the water in the churn by introducing a steam hose into it, is objectionable because the resulting vibration may damage the churn unless a properly installed noiseless water heater is used.

Sterilizing Churn by Means of Live Steam.—Sterilization of the wooden churn by means of live steam is not recommended. Experience has shown that steam fails to penetrate the water-filled pores of the wood sufficiently rapidly to accomplish efficient germ destruction. Steam sterilization of churns is objectionable further because its severity takes the "life" out of the wood, and because of its tendency to fill the atmosphere of the factory room with fogs of free steam. Especially during the cold season this condition causes profuse sweating of walls and ceilings, shortening the life of belts and motors, and encouraging mold development.

Treatment of Sticky Churns.—The condition of the wood that causes the buter to stick to the churn barrel and worker rolls, is caused either by insufficient chilling of the churn before use, or by the fact that the pores of the wood have become filled with grease, curd, milk salts and possibly neutralizer ingred-

ients, such as lime. Churns that receive the proper daily cleaning treatment, as outlined in the foregoing paragraphs, never develop stickiness.

There are principally two kinds of treatment that have been found suitable for reconditioning sticky churns, namely, the acid treatment, and the rock salt treatment. Either of these treatments, if properly applied, will remove the conditions that cause the butter to stick to the churn, without damaging the churn.

Acid Treatment.—This consists of using water to which about one quart of commercial sulphuric acid per 100 gallons of water has been added. Running the churn drum containing this acidified water for about one hour, is usually sufficient to eliminate the sticky condition. The action of the acid lies in dissolving the material that is choking the pores of the wood.

After the acid treatment, the churn must be immediately and thoroughly rinsed out with plenty of water. If the churn is not used until the day following this treatment, the water rinse, should be followed by a second rinse of water to which a small amount of soda has been added. This will neutralize any traces of acid which, if left in the churn over night would intensify corrosion of metal parts. The acid treatment obviously encourages corrosion of non-resistant metal parts. However, if followed by rinses as above suggested, the possible damage is negligible. When pouring the strong acid into the water in the churn, care must be taken that none of the undiluted acid is spilled direct on the wood.

Rock Salt Treatment.—This consists of adding about 300 pounds of coarse rock salt to the standard size factory churn. A few gallons of water are then poured into the churn to make a thick mash. The churn drum is then run in high gear from three to five hours. The action in this case is largely mechanical. The friction produced by the tumbling and sliding of coarse salt mush in the rapidly revolving churn drum, scours the wood surfaces, and the moisture in the mush further assists in lifting the refuse that is choking the pores. This treatment is followed by several rinses with water to remove the salt and its impurities. The churn is then given a final scalding rinse before chilling it preparatory to churning.

WOODEN PACKING AND PRINTING EQUIPMENT

Packing Tools.—These consist chiefly of butter tampers and ladles. Because of their accessibility, they are easily kept in sanitary condition and yet, in the absence of proper treatment, they may become a source of butter contamination.

These tools should be made of hard, close-grain, solid wood, resistant to dampness, and with minimum tendency to crack, sliver, splinter or become fuzzy. They should be kept smooth and intact to prevent wood particles from breaking away and becoming incorporated in the butter.

They need a thorough washing and scalding after each day's use, should be allowed to dry over night, and are best kept in cold brine during the day, so that they may always be in proper condition for immediate use.

Butter Cutting and Molding Machines.—The construction of these machines is described in Chapter XVII on "Packing Butter." They consist largely of two types; namely, cube cutters of the Friday, Simpson, and Miller type, and continuous cutting and molding machines with Archimedean screw, of the Doering, Benhil and Kustner type.

Cube Butter Cutters.—The wooden cubes should be kept in proper repair and at the end of the day's use they should be thoroughly scrubbed with brush and hot water containing washing powder. After a thorough rinse with scalding hot water they should be stored in a clean place and under conditions that will facilitate ready drying. The next day before use they need a good rinse with scalding hot water followed by cold water. If not used for several days, they should be washed again with hot water containing washing powder, scalded, and chilled before use.

Continuous Butter Cutting and Molding Machines.—The wooden hoppers and hopper boxes of these machines have proved a menace to the quality of the butter, fully as serious as the wooden churn. The construction, especially of the hopper boxes, involves a multitude of joints which, in the presence of moisture, soon expose cracks and cavities that catch and permanently conceal milk constituents, creating a condition that causes products and germs of putrefaction to contaminate the butter that passes through the machine. This may lead to

repeated, disastrous epidemics of serious bacterial flavor defects in print butter. While, by heroic treatment of these wooden hopper boxes, damaging contamination can be prevented, the danger is ever present. Since metal hopper boxes that eliminate this danger with certainty are now available, the permanently surest means of avoiding the possibility of damaging print butter defects resulting from the use of the continuous butter cutting machine, lies in replacing wooden hopper boxes by metal ones.

For details of the sanitary care of butter cutting machines and other print room equipment see Chapter XVII on "Packing Butter."

Butter Trucks.—Butter trucks into which churnings are loaded for chilling and future printing, constitute a type of wooden equipment in which the butter usually comes in direct contact with wooden surfaces. They, therefore, need continuous sanitary care in order to prevent them from becoming sources of damaging contamination of the butter. Similarly as the boxes of the cube butter cutter, these butter trucks should be thoroughly cleaned with hot water containing a suitable washing powder, at the end of the day's use, then well-rinsed with scalding hot water and stored in a clean, dry place where they may dry quickly. The next day, immediately before use, they need a good rescalding and chilling. If not used daily, they are prone to develop mold. Butter trucks that have been lying idle for several days, therefore, should receive the regular washing and scalding treatment just before the next use.

Buttermilk Tanks.—Most buttermilk tanks are of wooden construction. While they do not come in contact with butter, and are usually located outside of the butter making room, they need to be kept in sanitary condition in order to prevent mold growth and objectionable odors that pollute the atmosphere of the creamery.

The usual acid condition of the buttermilk assists in preserving the wood of these tanks. The buttermilk, when held in them for a considerable period, however, tends to undergo decomposition, generating foul odors, especially during the hot weather season. Wherever possible, it is desirable to arrange for the frequent and complete emptying of the buttermilk tanks, preferably daily and at least weekly. The buttermilk tank

should be cleaned out once per week, removing all remnants of milk constituents, and steaming the cleaned tank.

Sweet Water Tank.—This tank is usually of wood construction. It supplies the water used for washing the butter. It is of the greatest importance, therefore, to give it such care as to guard against avoidable contamination of the butter wash water. Its sanitary care was discussed in Chapter III under the heading "Sweet Water System."

METALS IN CREAMERY EQUIPMENT

In the construction and use of equipment that requires high tensile strength and hardness, or in which the milk and cream must be heated or cooled, or both, metallic surfaces are indispensable. This refers particularly to forewarmers, pasteurizers, ripening vats, pipes and pumps, cream strainers, butter culture tanks, cream coolers, and the like.

In addition to mechanical suitability and physical fitness, the effect of metals on the flavor, keeping quality and wholesomeness of the butter demands careful consideration. It is now well known that some metals, their salts and oxides, when in contact with cream or butter, are capable of inducing chemical reactions of complex and widely varying nature, and that may and often do play an important part in the progressive deterioration of the flavor of butter. Furthermore, some metallic compounds have toxic properties. This is particularly true of certain salts of lead, and of oxides of copper.

Damaging Effect of Metals on Butter Due to Metallic Corrosion.—The presence in cream and butter of metals or metallic compounds is usually the result of some form of metallic corrosion. The metal of the equipment must be attacked yielding soluble oxides or salts in order for it to be capable of affecting and damaging the quality of the cream and butter.

Metallic corrosion may result from prolonged action on the metal, of the organic acids contained in the cream, such as lactic, butyric, citric, acetic, carbonic acids, forming salts with such metals as copper, iron, zinc, etc., that are damaging to flavor and keeping quality of the milk product. The milk salts, and even such colloids as casein and albumin may also play at least a limited role in such corrosion.

Corrosion Due to Electrolysis.—The corrosion may be due to or intensified by electrolytic action. This may happen, for instance, when two metals of different electrical potentials are in contact with one another and are immersed in the cream. In this case we have a typical electric battery, the cream representing the electrolyte. This battery produces a galvanic or electric current, and this action is always accompanied by the corrosion of at least one of the metals in the battery.

The metal that is attacked and that will corrode in such case, is the metal that is electro-positive to, or that is less noble than the other metal in this battery (the equipment containing the fluid dairy product); and the metal that will be protected from corrosion is the metal that is electro-negative to, or that is more noble than the other metal. Copper is a more noble metal than tin. It is electro-negative to tin. Hence, if a tinned vat contains bare copper in contact with the tinned surface, the tin will corrode. Copper is electro-negative to practically all metals used in creamery equipment, its contact with any other metal submerged in the milk or cream, therefore, causes electrolysis that will corrode the other metals. Aluminum, on the other hand, is electro-positive to most metals used in creamery equipment. It is less noble than the other metals. Its presence in contact with tin, for instance, on the milk side of the equipment, will protect the tin against corrosion while the aluminum suffers corrosion. Tin corrosion, therefore, can be prevented by the presence of aluminum in contact with the tinned surface in the equipment.

It is not necessary to have two metals present in a vat to produce electrolysis. The presence of a metal alloy may do the same thing under certain conditions. An alloy is generally looked upon as a single metal, resulting from the fusion of two or more metals into one. This usually is true of the molten mass. But it often happens that during the cooling of the hot, molten mass, this fusion is disturbed and one or another of the metals in the alloy segregates. In such case the alloy acts in a similar way as two metals in contact with one another. It constitutes an electrical couple and, when immersed in an acid liquid like cream it induces electrolysis. This is true to some extent of the so-called white metals which are metallic alloys that contain considerable and varying amounts of copper. This

is one of the reasons why coils and linings of cream vats constructed of white metal, render such equipment unsafe for use in the creamery. These alloys tend to promote the development of metallic and other oxidized flavor in cream and butter. Recent work by Roadhouse and Henderson[13] showed, however, that the presence in the copper-nickel alloy, of tin and zinc in amounts ranging from 3 to 8% tin and 3 to 4% zinc, tended to inhibit the solution of copper, to reduce the corrosion rate in milk and to delay the development of oxidized flavor.

Even one single metal may cause electrolysis if the metal contains impurities, such as slack, or dross, or other material not fully removed in the smelter. These impurities in contact with the metal itself represent electric couples and when immersed in the cream may yield a galvanic current.

Electrolysis is frequently due also to the presence in the factory of stray electric current from poorly grounded or incompletely insulated motors, or defective conduits, or from currents leaking into the plant from outside sources, such as power houses, electric lines, street car tracks, etc.

Metallic corrosion is affected by many conditions prevailing in plant operation. It is usually intensified by prolonged time exposure, large ratio of surface to volume, high temperature, exposure to air and light, large amount of air dissolved in the milk product, and other factors. Vats, forewarmers, cooling coils, sanitary pipes, etc., to the surfaces of which adhere remnants of milk or cream from one day to another, are prone to suffer metallic corrosion while not in use. The metallic salts so formed contaminate the next day's cream, unless the entire system is scoured and thoroughly flushed out with hot water before the cream is allowed to circulate through it. Insanitary condition of the equipment is a very active factor in causing corrosion and metallic contamination of cream and butter. Metallic surfaces that are kept bright and shining are usually free from metallic salts and oxides. Metallic corrosion in unclean cans and separators on the farm is responsible for much of the poor quality cream arriving at the factory.

How Metallic Salts Deteriorate Cream and Butter.—It was shown by the work of Rice and Miscall,[4] that when milk is separated, the copper dissolved from plant equipment is distributed in the cream and skim milk in proportion to the water

content of each. Davies[5] further found that the metal enters into protein combination, that rich cream contained more metal proteinate than cream low in fat, and that the ratio of metal proteinate increased in butter over buttermilk, indicating that metal proteinate is adsorbed to and concentrated on the surface of the fat globules. This emphasizes the potential danger of damage to the quality of buter due to metallic contamination of cream received in rusty cans, or handled in equipment that exposes bare surfaces of damaging metals, such as copper, copper alloys, iron, zinc, etc. The presence of metallic salts in cream may deteriorate the flavor of the cream and damage the flavor and keeping quality of the butter in a variety of ways. The more important of these are: direct addition to the product of metallic flavor due to the presence of such salts; absorption by the product of metallic flavor from these salts; action of metals and their salts as oxidizers or as catalyzers; and also the selective action of metals on bacteria.

Metallic Flavor Due Directly to Presence of Metallic Salts.—Most metals used in dairy equipment are more or less soluble in lactic acid and other milk acids. Their solubility may or may not be accelerated by the milk salts and the milk colloids. Some of the metallic salts so formed have, themselves, an intense puckery, metallic flavor. This is particularly the case with the salts of copper and to a lesser extent of zinc and iron salts. It follows, therefore, that the presence of the salts of these metals in cream or butter conveys to these products a metallic taste. In this case, the larger the amount or the more intense the metallic taste of the salt itself, the more pronounced will be the metallic flavor of the cream and butter.

Metallic Flavor Absorbed by the Butter.—Butter fat readily absorbs flavors and odors from other substances with which it comes in contact. The addition of starter to cream conveys to the butter a starter flavor. This flavor is distinctly noticeable, even when the starter is added only just before churning, though practically all of the starter itself is removed from the butter with the buttermilk and wash water. In a similar way, butter fat is capable of absorbing the flavor of metallic salts when they are present in the cream. In this case the butter may actually be metallic in flavor when taken out of the churn.

Flavor Deterioration by Metals Due to Oxidative Deterioration in Butter.—The more serious consequences of metallic salts in cream and butter are not of such simple nature. They are due to reactions far more complex than the mere physical presence of salts with metallic taste, or the simple mechanical absorption of the metallic taste from the salts by the butter fat. These more complex reactions have to do with changes that go on in the butter after manufacture, and which greatly hasten its deterioration.

For example, the metal causing the trouble may be an oxygen-carrier. Metals that are called oxygen-carriers have the property of themselves readily taking up oxygen in the form of oxides, and of subsequently surrendering this oxygen to substances with which they come in contact, and which have a greater affinity for oxygen. The presence of these metals and their salts, therefore, induces or accelerates oxidation in the butter, and thereby causes progressive changes which shorten its life, hasten its deterioration in quality, and produce a variety of commercially highly objectionable off-flavors, such as fishy flavor, tallowy flavor, etc. Copper, for instance, is a very active oxygen-carrier and so are many of the alloys containing copper. Iron also has similar properties but to a lesser degree.

Flavor Deterioration by Metals Due to Catalytic Action.—The flavor-and keeping quality-damaging effect of metals is further intensified by catalysis. Metals are active catalysts for many reactions in organic chemistry. Through catalysis they are capable of activating the dissolved oxygen in the milk product, causing fat oxidation, even when they are present in amounts too small to impart a metallic flavor. By catalyzing the oxidation, the rapidity and intensity of the development of tallowy flavor are augmented. Catalysis of the hydrolysis reaction of lecithin accelerates the production of fishy flavor. Both copper and iron are active catalysts.

Metals Influencing Bacterial Action.—Experimental results have demonstrated that certain metals may affect the flavor of cream and the keeping quality of butter through their influence on bacterial growth. These studies indicate that the influence of metals on bacteria is selective, that is, a metal may retard or inhibit the growth of some species, accelerate the activity of others, or have no effect on still others.

Our knowledge regarding this phase of metallic influence is very limited, especially from the standpoint of its effect on cream and butter, but isolated experimental data show, unmistakably, cases where the presence of copper had a retarding effect on lactic acid fermentation, and accelerated the activity of putrefactive organisms. In other cases, it was found also that the presence of metals changed the products of bacterial activity, and caused a metallic taste.

It is entirely conceivable, though not experimentally proven, that the objectionable metallic flavor so prevalent in some of the cream received is due, in part at least, to the activity of bacteria that thrive in, or demand a medium containing metals or metallic compounds. They thus may derive their supply of metallic salts from unclean separator bowls, unclean and rusty cream cans and other milk utensils in similar insanitary conditions. Bacteria known as iron bacteria have been found to be capable of producing a metallic flavor in dairy products in the presence of iron.

Metals Destroying Vitamins.—Aside from the damaging effect of the action of some metals on such commercial properties of butter as flavor and keeping quality, their presence may also injure the vitamin strength of the butter. The chief vitamin of butter is vitamin A. This vitamin is sensitive to and may be destroyed by oxidative processes. If the cream or butter is exposed to or harbors metals or metallic compounds that are oxygen-carriers, such as copper and copper salts, for instance, its vitamin strength may become diminished. Here again the salts and oxides of copper are by far the most active. Iron and iron salts react in the same direction but their action is much less intense. The presence or absence of products of corrosion on the metal surfaces themselves largely determines the quantity of metallic salts that may pass into the cream and butter. Thus, unclean or tarnished copper surfaces yield more copper salts in solution than polished copper surfaces. From the standpoint of the protection of the vitamins alone, therefore, it is of the greatest importance that metallic surfaces be kept clean, bright and shining.

Wholesomeness of Product Jeopardized by Toxic Properties of Metals.—Some metals, their salts and oxides, have distinct poisonous properties and their presence in butter and

other dairy products would obviously jeopardize the health of the consumer. Metallic poisons are usually cumulative in their effect. That is, the poison is not voided by the system, and continued consumption of even very small quantities may, in the long run, prove highly toxic.

The toxic properties of lead are well known. Fortunately, this metal is not used now in dairy equipment except in the form of solder which, when properly applied, represents a negligible area of exposure. Tin, iron, nickel and aluminum are comparatively negative in this respect, but copper oxide (verdigris) stands out as a metal product of distinct toxic properties.

SUITABLENESS OF METALS FOR BUTTER MANUFACTURE

The metals, metal coatings and metal veneers, structurally and economically suitable, that are available for the construction of the milk, cream or butter side of creamery equipment are principally as follows:

Single Metals: Iron, copper, nickel, aluminum.

Plated Metal Coatings: Tin, zinc, chromium, metallized coatings, Lythcoting.

Metallic Alloys: Copper alloys, such as nickel silver, white metal, etc.; chrome-nickel-steel alloys, such as Allegheny steel 18-8, Enduro KA_2, etc.: Chrome-nickel alloy, such as Inconel; aluminum alloys.

Metallic Veneers: Chrome-nickel-steel on iron, such as Ing A-clad and Plycrome-clad; chrome-nickel on iron, such as Inconel-clad steel; nickel on iron, such as nickel clad steel; pure aluminum on aluminum alloy, such as Alclad; glass enameled steel; rubber-lined steel.

Single Metals.—From the foregoing discussion of the effect of metals on flavor and keeping quality of butter it is evident that **bare** surfaces of **iron** or **copper** exposed to the milk or milk product, may be expected to be damaging to the quality of the resulting butter. Both metals are attacked by, and are soluble in milk and cream. They are attacked by milk acids, caustic cleaners and neutralizers. Iron suffers intense corrosion also in contact with chlorine sterilizers, both hypochlorites and chlora-

mines, and in refrigerating brines. Copper shows noticeably better corrosion resistance to chlorine sterilizers and is more resistant also to brine.

Copper salts have an intense bitter, puckery, metallic taste and are active oxidizers and catalyzers, encouraging progressive flavor deterioration due to chemical action. They are detrimental to the flavor and keeping quality of butter. Iron has similar properties but to a somewhat lesser extent.

Nickel is noticeably soluble in organic acids such as are contained in milk and cream. Its salts, however, have a mild metallic flavor only, and they do not appear to cause chemical reactions in butter that are damaging to its flavor. Nickel is suitable for use in the construction of milk and cream holding tanks. Likewise the use of all nickel coil vats for the pasteurization of cream by the holding process (145° F or higher for 30 minutes), followed by cooling and holding over night, appears to be entirely harmless to the flavor and keeping quality of the butter, although the nickel surface in such vats suffers noticeable tarnishing. The daily use, in butter manufacture, of a 600 gallon all-nickel cream pasteurizing vat, has been under observation by the author over a period of 12 years, involving approximately 4,000 churnings, and in no case was there any indication of flavor defect, or lack of keeping quality, due to the use of the nickel vat. The majority of these churnings were not only pasteurized and cooled, but held over night in this vat.

On the other hand, commercial use of all-nickel surface coolers for milk and cream, has demonstrated the severe corrosiveness of nickel in contact with the hot milk product, causing the topmost tubes of the upper coil section, that receive the hot milk direct from the pasteurizer, to yield to early corrosion. It is believed that this is principally due to the corrosive action of the gases dissolved in the heated milk product. This suggests that nickel is unsuitable for the top section of the surface cooler, but would be serviceable for the lower sections and the bottom trough. Experimental results by Laque and Searle[6] indicate that corrosion in an internal tube all-nickel heater, heating milk from 45 to 145° F. is negligible, due to the formation of a protective film on the nickel surface in this type of equipment and operation. Nickel is suitable also for sections of internal tube coolers from about 80° F. down, and for direct

expansion ammonia coolers at and below this temperature range.

There is reasonable doubt, however, regarding the suitability of all-nickel equipment for starter making and for the preparation of acidophilus milk, because of the sensitiveness of nickel to high acid dairy products. The danger of damage in such case is augmented by the tendency in the direction of heavy air incorporation in a product of such sluggish consistency and by the usual way this product is handled. While available results indicate no intense metallic flavor from nickel in dairy products, yet there is an unmistakable tendency toward a slight metallic and bitter flavor in the case of acidophilus milk, and butter culture.

Nickel surfaces are unsuitable also in equipment used for the manufacture of cottage cheese, because of the danger of a green discoloration on the curd, due to the formation of nickel lactate. The corrosion of nickel can be prevented, however, by contacting the nickel in the equipment with a less noble metal, such as aluminum.

As far as direct contact of butter with nickel is concerned, the early work of Hunziker and Hosman[7] showed conclusively that nickel in butter does not cause progressive flavor deterioration. Prolonged contact of nickel with butter failed to produce metallic or other off-flavor in butter. It, therefore, is well-suited to the construction of butter cutting and molding machines.

Aside from its solubility in lactic and other milk acids, and its sensitiveness to the gases dissolved in heated milk, nickel is practically immune to alkaline cleaners, chlorine sterilizers, refrigerating brines and neutralizer limes. In this respect it is the most suitable single metal, satisfactory for use without plated surface, that is available for creamery equipment.

Aluminum has proved its merit as material of construction of creamery equipment in European factories. Its solubility in the milk product is negligible. Its salts are of very mild metallic taste and their oxidative and catalytic tendencies in milk products have been found sufficiently negative to render their presence harmless. Their toxic properties are considered nil. Aluminum is admirably resistant to corrosion in the presence of water, milk and cream, and to their acids, and to carbonic acid. Its resistance to corrosion is believed due to the formation on

its surface of a protective oxide film when exposed to the air. Aluminum has a high heat transmission efficiency and excels in lightness of weight.

Because of these favorable attributes, aluminum has proved highly serviceable for the construction and use of milk and cream holding tanks and transport tanks, pasteurizers, coolers, cream ripeners and shipping cans. In trials with aluminum cream cans in commercial service, Hunziker observed a complete absence of the metallic taste of sour cream in contact with the sides of the cans. Aluminum milk and cream shipping cans are widely used in European countries. Wooden containers lined with aluminum have also proved serviceable. Aluminum foil between two thin sheets of parchment paper, as a liner for wooden butter cubes, has found extensive use in New Zealand, as the most effective means of retarding or preventing surface deterioration of butter held in storage. See also Chapter XVII on "Packing Butter."

The resistance of aluminum to corrosion increases with its purity. Aluminum used in dairy equipment should be at least 99% pure. Impurities in the metal, such as particles of other metals, dross, or slag, also pores, incite corrosion, causing destructive pitting. Rough and uneven seams also tend to give rise to localized corrosion. Contact with nobler metals, such as iron, copper, bronze, etc., in aluminum equipment must be avoided, in order to guard against intense corrosion due to electrolysis. Because of its limited hardness, aluminum construction must be somewhat heavier (thicker walls) than is sufficient for the harder metals and alloys, depending on the particular type of the equipment and its intended use.

Aluminum is attacked severely by alkalies, such as are used in washing solutions. This drawback is readily overcome, however, by addition to the alkaline washing solution of a small amount of sodium silicate. In the case of soda ash (Na_2CO_3) the addition of .05% sodium silicate, originally recommended by Seligman,[8] is sufficient. In the case of caustic soda a larger amount of silicate is necessary to insure corrosion protection. According to the exhaustive study of Mohr and co-workers,[9] for washing solutions containing from 0.1 to 1.0% of caustic soda, the addition of from 0.6 to 6.0% sodium silicate, respectively, will fully protect aluminum surfaces against attack.

There are now on the market specially prepared washing compounds that protect aluminum surfaces against corrosion; such as Oakite Aviation Cleaner, and J. B. Ford Co. Cherokee Cleaner.

Aluminum construction is not suitable for equipment used for the neutralization of cream, such as forewarmers and cream vats, because of the lack of corrosion resistance of aluminum to alkaline neutralizers. Aluminum is also severely attacked by refrigerating brines that are on the alkaline side. Such corrosion is greatly minimized in the presence of sodium silicate or chromate in the brine. Aluminum shows good resistance to chloramine sterilizers, and to hypochlorite sterilizers when not alkaline. In alkaline hypochlorite it corrodes severely.

Plated Metal Coatings.—Tin, while slightly soluble in milk and cream, yields salts with a relatively mild metallic taste and which have been found sufficiently inert to cause no damaging chemical action in the dairy product. While its softness precludes its use in creamery equipment as a single metal of solid tin, it lends itself admirably for the coating of other structurally better suited metals of relatively low material and fabricating costs, such as iron and copper, protecting them against corrosion and making them harmless from the standpoint of the injurious action of their salts on the flavor and keeping quality of butter.

The usefulness of tin plate, which is sheet iron tinned, for the construction of the smaller and more or less accessory creamery equipment, such as cream separator parts, weigh cans, cream troughs, pails, etc., which does not require great rigidity, nor high heat conductivity, and the proper care of which is simple, is well known. The general quality and durability of tinned iron, however, is not very high. While relatively low in price, tinned iron does not stand up well in the construction of milk and cream holding tanks and its vulnerability to rusting in the case of milk and cream shipping cans is a constant menace to the milk product. The danger of damage to quality is especially great in contact with sour cream. Upon its arrival in tinned steel cans at the creamery, sour cream nearest the side of the can almost invariably tastes distinctly metallic.

The efficient **tin coating of copper** is making copper highly suitable for the milk and cream side of all equipment, where its

limited rigidity does not bar it, such as for linings and coils in cream vats, tubular milk and cream coolers, sanitary pipes, etc. The permanency of the tin coating, however, leaves much to be desired, especially in the case of tinned heating surfaces that become coated with insoluble material such as the proteins and mineral salts of milk (milk stone), for the removal of which strong alkalies, or abrasive detergents must be used. This is particularly noticeable in the case of heating surfaces with excessively high temperatures, such as the linings of steam-jacketed flash pasteurizers, the first few coil convolutions in pasteurizing vats, etc. The tin coating on such heating surfaces is usually of short duration, requiring frequent retinning. This is true also of tinned copper sanitary piping, especially the sections of the cream line between flash pasteurizer and cooler, and the piping used in connection with the direct steam pasteurizer. In these pipes the condition of the tinned surface is difficult to examine and there is danger of the presence of unobserved imperfections accompanied by the formation of verdigris that contaminates the milk product with copper salts. An additional weakness of tin coated metal surfaces lies in the tendency of tin corrosion that yields black spots. For discussion of cause and prevention see "Black Spots on Tinned Surfaces" later in this chapter.

Tin is noticeably soluble in the milk acids. It suffers intense corrosion in the presence of caustic alkalies, but is reasonably resistant to neutral sodas such as Wyandotte cleaner and cleanser and sesquicarbonates. It is protected against corrosion by the presence of sodium dichromate, such as is contained in so-called "tin cleaners." For the protection of the tin coating in milk and cream cans caustic alkalies should not be used in can washing. Tin surfaces resist chloramine sterilizers, but suffer considerable corrosion in the presence of hypochlorite sterilizers. Tin is attacked to a considerable extent by refrigerating brines, particularly in alkaline salt brine. Tin corrosion in brine is greatly diminished in the presence of sodium dichromate, or sodium silicate.

Chromium plating of the milk, cream or butter side of equipment presents a surface that is inert from the standpoint of its effect on the dairy product. The fact that earlier attempts to use chromium plated equipment in the creamery failed to

prove satisfactory on account of the high cost and short life of chrome-surfaces, tended to discourage its use in the creamery. The present state of perfection of chrome-plating suggests that it may prove of real service in future creamery equipment.

Nickel plating likewise provides satisfactory protection of the milk products against damaging reactions caused by the base metal, as long as the coating remains intact. Its chief drawback, however, lies in the tendency of the nickel coating to peel off, exposing the base metal and incorporating objectionable particles of nickel in the butter.

Zinc plating or galvanizing protects the iron in two ways; namely, by a surface coating of zinc, and by the fact that zinc, being a less noble metal, is electro-positive to iron. This means that in the presence of an electrolyte, such as the fluid milk product, the iron remains protected while the zinc suffers corrosion. Damaging iron salts are, therefore, not formed, but this advantage is offset by the fact that the zinc salts so formed are equally objectionable, having themselves an intense astringent metallic taste, causing damaging chemical reactions in the dairy products, and having toxic properties. Galvanized iron is unsuitable for the milk side of creamery equipment. In some countries its use for such purposes is prohibited by law. Galvanized iron pipes should not be used for milk and cream lines.

Metallic Alloys.—Copper-nickel alloys, such as nickel silver, ambrac and similar alloys generally known as white metal, have great merit structurally and because of their usually unchanging attractive appearance give a general impression of suitability for creamery equipment. As explained in earlier paragraphs under "Corrosion Due to Electrolysis," these alloys may and often do cause electrolytic action that seriously jeopardizes the flavor and keeping quality of butter.

The extent of their damage depends largely on the amount of copper they contain. In general, the higher their copper content the greater the danger of damage to the dairy product. Their use in creamery equipment in which the dairy product is heated, or in which it is ripened to a considerable acidity, or for pipe lines conveying hot milk or cream, is unsafe regardless of percentage composition. As previously indicated,[13] the flavor-jeopardizing tendency of these alloys is diminished by the

presence, in their composition, of certain percentages of tin and zinc.

For the cold handling of the milk product they may be used, provided that their copper content is reasonably low. Monel metal, for instance, has a relatively low percentage of copper, and has been found highly suitable for use in the construction of butter cutting and molding machines. It is also used to some extent for milk and cream holding tanks.

Aluminum Alloys containing copper or bronze are unsuitable for use in creamery equipment for similar reasons as apply to copper alloys. Aluminum alloyed with small amounts of manganese and magnesium, conveys to the aluminum greater hardness and protection against mechanical damage. The resistance of this alloy to milk acids and its negative effect on flavor and keeping quality are similar to those of pure aluminum. It is not known to damage the milk product. It yields to corrosion in the presence of alkalies but similarly as in the case of pure aluminum, its corrosion in the presence of alkaline washing solutions is prevented by the use of the corrosion-protective compounds suggested under "Aluminum." Because of its superior hardness, this aluminum alloy is particularly suitable for the construction of aluminum milk and cream shipping cans.

Stainless Steel Alloys, such as Allegheny metal 18-8 and Enduro KA2, of a composition within the general range of a chrome-nickel content of 18% chromium and 8 to 14% nickel, have now been used in diverse milk plant and creamery equipment over a sufficient period of years to demonstrate their superiority. They are insoluble in milk and cream, sweet or sour, hot or cold, and have no effect on flavor and keeping quality of milk products. They are not attacked by the milk acids nor by alkaline washing powders, or chemical sterilizers. They are suitable for milk and cream coolers under conditions that bar the use of tinned copper tubes, such as in the presence of sulphur water, or direct expansion ammonia. Stainless steel is ideal also for steam- and hot water-jacketed flash and vat pasteurizers, liners for forewarmers and coil vats, for wire mesh cream strainers of every range of mesh size, etc. It has not proved entirely satisfactory for helical coils in vat pasteurizers used for both heating and brine cooling, on account of early interior corrosion, particularly around welds.

Stainless steel is highly suitable also for use in the construction of butter cutting and molding machines, and for churn bolts and other metal parts in the interior of the churn drum. These stainless steels, high in chromium and nickel may be distinguished by the practical creameryman from ordinary stainless steels by the fact that the former (of the 18-8 composition) are non-magnetic while the latter, which contain little or no nickel and are known as chrome-steel alloys, are magnetic.

Chrome-Steel Alloys usually contain about 13 to 14% of chromium and no nickel. These ordinary stainless steels are magnetic. While they are highly resistant to corrosion and, therefore, suitable for many purposes for which the chrome-nickel steels are used, they do not stand up quite as well under certain creamery conditions. When purchasing stainless steel equipment for the creamery, it is wisdom, therefore, to specify "18-8" (18% chromium and 8% nickel), and as a further precaution the equipment may be tested with a magnet. 18-8 steel is non-magnetic.

Chrome-Nickel Alloy, known as Inconel, is a nickel alloy containing approximately 14% chromium. This alloy is of more recent introduction in dairy equipment than nickel and stainless steel. It has been in increasing use for nearly a decade, however, and has demonstrated its suitability for every type of milk products equipment. It surpasses 18-8 stainless steel for vat coils and resists corrosion in the milk product under practically every range of temperature, acidity and air exposure encountered in plant operation, is resistant to alkaline washing solutions, and to limited exposure to chlorine sterilizers, and it possesses good resistance to refrigerating brines. Similarly as non-magnetic stainless steel, it is suitable for direct expansion ammonia milk and cream coolers.

Nickel alloys containing copper, on the other hand, have similar objections for creamery equipment as copper alloys. The larger the ratio of nickel to copper the less the potential danger of impairing the dairy product. In general, however, they are not safe to use on the milk side of creamery equipment.

Metallic Veneers.—Efforts to reduce the cost of the corrosion-resistant and highly satisfactory chrome-nickel steel, chrome nickel and nickel surfaces in dairy equipment have re-

sulted in the development and perfection of the art of lining ordinary steel with a thin sheet of corrosion-resistant alloy or metal. These efforts have brought forth several new products known by their respective trade names as IngA-Clad, Plykrome, Inconel clad and nickel clad.

When used in the construction of dairy equipment, the non-corrosive veneer is on the milk side, thus providing similar protection of the milk against metallic corrosion and damage to flavor as would be the case with solid walls of chrome-nickel steel, chrome-nickel, and nickel, respectively, but at considerably lower material cost. A similar type of product is available also in the form of a pure aluminum covering or veneer over an aluminum alloy.

Glass Enamel Steel has been successfully used in the construction of dairy equipment for several decades. The glass enamel has proven a complete protection to milk against damage from metallic salts. It is not acted upon by the milk and it has no damaging effect on the flavor and keeping quality of the milk product. While the enamel coating is not indestructible, its durability under normal conditions of use is sufficient to preserve it in satisfactory condition over a considerable period of service. The low heat conductivity of both the glass enamel and its heavy background of steel, and the corrosive character of the steel side, renders glass enameled steel unsuitable as a heating and cooling surface. The proper place for glass enameled steel lies in its use for linings of coil vats and for shells of milk storage tanks. For these purposes it has amply proven its great usefulness and satisfactory service.

Lithcoting Creamery Equipment.—Lithcote is a compound prepared for the permanent coating of tanks. It is manufactured and applied by the Lithgow Corporation of Chicago. The exact composition of the compound appears to be a trade secret. This compound may be sprayed or brushed on the metal surface. The application is made at a temperature of approximately 400° F.

Lithcote has been in successful use in connection with brewery equipment for a number of years. Its introduction in the dairy field is comparatively recent, and it has not been in use in milk plants and creameries sufficiently long to justify final conclusions regarding its lasting qualities. However, lab-

oratory tests with lithcote-covered bars of iron by Hunziker, Cordes and Behlmer[10] indicate that it is not affected by steam, weak alkalies, weak acid solutions, hypochlorite sterilizers, nor milk stone remover. Likewise cream, high acid or neutralized, has no effect on it, and the lithcote appears to be entirely inert toward the milk product. It has no effect on the flavor of cream or butter.

Lithcote is gradually affected in the presence of refrigerating brine, its color changing to a greenish red. It also is sensitive to alkalies in hot solutions. Strong alkali solutions are definitely harmful to it. The effect is particularly pronounced when these solutions are hot.

As far as the use of lithcote in the creamery is concerned, the performance of a 1,000 gallon cream holding tank covered with lithcote, that has been in daily use and under observation by the author for one year, suggests that lithcoted steel tanks for the cooling and holding of milk and cream are suitable. Lithcoted vat liners also should prove satisfactory. Lithcoted steel churn bolts, likewise, have proved suitable. Lithcote is serviceable also for repatching glass enameled tanks, where the enamel coating has become defective. The lithcote permits of feathering at patched edges and thereby is capable of a smooth union between lithcote and glass enamel.

Whether lithcote is sufficiently permanent, and resistant to all conditions of use in the creamery to take the place of glass enamel, is a question the correct answer to which requires more experience in the use of lithcoted creamery equipment. Its outstanding advantage is that of economy. Lithcote is much cheaper than glass enamel.

Metallizing Creamery Equipment.—Metallizing is defined as a process of metal-coating of objects by spraying. A wire of the metal desired to use for the coating is fed into a pressure spray gun where it is melted by the oxy-acetylene flame (Temp. 6500° F.). Compressed air jets force minute globules of molten metal out of the gun at a high velocity. The metallizing metal adheres to any clean, oil-free, roughened surface, whether metal, glass, wood, cloth or concrete.

Metallizing is an economical means of prolonging the life and usefulness of steel tanks, such as glass lined vats the steel side of which has rusted through, or leaky brine tanks, or tanks

of any metal that has worn down in spots, making the tanks unsafe or unsuitable for further use as they are. For the outside of tanks, metallizing with zinc is very effective. For the milk side tin is used. Tanks so treated are mechanically as good as new. Metallizing with tin or other suitable metal for the milk side of metallic equipment, provides perfect protection of the dairy product.

Metallizing is feasible regardless of the type of metal that has become defective or worn down, and it permits the use of any metal or alloy desired for the coating. It is suitable not only for renovating tanks and vats, but also for building up any worn down mechanical parts, such as shafts, rotors and headers in pumps, etc. The coating can be built up to any desired thickness and if followed by buffing, can be polished to an evenly smooth surface, highly satisfactory from the standpoint of ease of cleaning. It is by far the cheapest and most effective means known, to recondition worn-down or rusted-out parts in creamery equipment.

CHOICE OF METALS FOR INDIVIDUAL EQUIPMENT

On the basis of the properties of different metals, as discussed in the foregoing paragraphs, the following metals appear most suitable for use on the milk side of the different types of equipment.

For Milk and Cream Shipping Cans.
Aluminum-manganese alloy, or tinned steel.

For Tank Trucks and Tank Cars.
Aluminum, nickel, stainless steel, or glass enameled steel.

For Milk and Cream Weigh Cans.
Tinned steel, tinned copper, or stainless steel.

For Cream Dump Tanks.
Tinned copper, stainless steel, or glass enameled steel.

For Forewarmers and Neutralizing Vats.
Body: Tinned copper, glass enameled steel, or stainless steel.
Coil: Tinned copper, nickel, or Inconel.

For Vat Pasteurizers.

Body: Tinned copper, glass enameled steel, nickel, or stainless steel.

Coil: Tinned copper, nickel, or Inconel.

Cover: Tinned copper, nickel, or stainless steel.

For Flash Pasteurizers.

Stainless steel, or Inconel.

For Surface Cooler and Regenerator, and for Internal Tube Cooler.

Tinned copper, stainless steel, or Inconel.

For Direct Expansion Cooler.

Stainless steel, or Inconel.

For Culture and Starter Vats.

Body: Tinned copper, glass enameled steel, stainless steel, or aluminum.

Coil: Tinned copper, Inconel, or aluminum.

Cover: Tinned copper, stainless steel, or aluminum.

For Cream Strainers.

Stainless steel, or Monel metal.

For Milk and Cream Sanitary Piping.

Tinned copper, or stainless steel.

For Butter Wash Water and Tempering Water Lines.

Galvanized iron.

For Cream Pumps.

Bronze, or stainless steel for lining and rotor.

For Cream Deodorizing Tanks.

Stainless steel, or glass enameled steel.

For Butter Printing Equipment.

a. **Boxes for Cube Butter Cutter.**

Wood, stainless steel, nickel, or Monel metal.

b. **Hopper Boxes for Continuous Butter Cutter.**

Stainless steel, or nickel.

BLACK SPOTS ON TINNED METAL SURFACES

Tin corrosion, such as causes the formation of black spots on tinned copper coils and linings in milk and cream vats, is an equipment defect of long standing, and the solution of its cause and prevention have been an exasperating problem to the creamery operator.

Factors Conducive to Formation of Black Spots. — The general observations of the factors that encourage this so-called tin-sickness in practical operation are supported by scientific study. They briefly are as follows: These black spots appear on tin plated metal surfaces of containers of milk and cream, sweet and sour. Their formation is especially rapid and pronounced near the air-liquid line; in proximity to bare copper, brass and bronze, such as near bronze nipples and valves in cream vats; on surfaces covered with remnants of milk solids or of washing powders; and at points of scratches or other damaged places.

Theoretical Data on Black Spots.—The causes and prevention of the formation of black spots on tin or tinned metal surfaces has been subjected to extensive study by Mohr and Schulz,[11] and by the International Tin Research and Development Council.[12] It is now generally conceded by the foremost students of the subject that, besides the acceleration of the formation of black spots on a tinned surface by contact with copper, this type of tin corrosion is of electro-chemical nature, as first suggested by Mohr and Schulz[11] who concluded that the black spots are directly due to dissolution of the tin and its transformation by anodic oxidation into a tin compound of black color. The main component of the black spots has been found to be stannous oxide.

Most commercial metal surfaces are covered with a more or less protective film. This is true also of tin. Brennert[12] demonstrated that a potential is produced on tinned copper surfaces and that this potential on the tin surface toward the solution (milk or cream) depends, among other things, on the continuity of the protective film. If the film is not continuous the potential is less noble, and protection against corrosion suffers. With increasing continuity of the film, the electrode shows an increasingly noble potential.

Brennert[12] further showed that the formation of black spots cannot begin on a free tin surface, until the surface potential has been increased (ennobled) above the dissolution potential. As soon as the surface potential has been raised sufficiently above the dissolution potential to permit the electric current to break through the film, the tin begins to corrode with the formation of black spots. Breaking through occurs at the weakest points of the film. The ennobling of the tin associated by black spot corrosion occurs more rapidly, the greater the content of oxygen in the solution. Pumping air through the fluid milk product increases the rapidity with which black spots appear.

Among the theoretical suggestions for the prevention of black spots offered by Brennert, that of changing the single potential of the tin surface, and that of reinforcing the protective film so as to prevent the current from breaking through, appear most promising for the practical prevention of black spots.

Practical Means to Prevent the Formation of Black Spots on Tinned Surfaces.—For the prevention of black spots by means of changing the single potential of the tin surface, contact of the tinned surface with another metal, less noble than tin, such as zinc or aluminum, must be provided. By thus forming an electrolytic couple, this less noble metal reduces the potential of the tin surface and prevents corrosion of the tin. This may be done by placing one or more plates of zinc or aluminum, preferably the latter because of its harmlessness to the flavor of the dairy product, into the cream vat or other equipment that exposes milk or cream to tinned metal surfaces. Brennert asserts that this method has been tried in the practical operation of milk vats and found to give very good results.

The second method that has practical possibilities, though obviously somewhat more uncertain in its operation and results, is to reinforce, or build up, the protective film. It has been the general observation in plant operation, that when newly installed tinned equipment is given special care from the standpoint of cleaning during its early use, the appearance of black spots is much retarded, if not prevented, even in the case of less efficient treatment later. This is probably due to the fact that initial corrosion is prevented by the special care, and later

corrosion is prevented or retarded because such early treatment made possible the building up or reinforcing of a sufficiently continuous film to protect the tin surface against corrosion.

Aside from, and in addition to the above preventive measures, dependable prevention of black spots necessitates elimination from the vat or other equipment of bare metals more noble than tin in contact with the tin, such as bare copper, brass or bronze, if such metals are present. In addition, it is essential to so perform the washing and sterilizing of the equipment, as to completely remove all remnants of milk solids, undissolved washing powder and chemical sterilizers, and to insure rapid and complete drying of the tinned surface, and keeping it dry while lying idle. The dry condition is usually best accomplished by giving the vat or other equipment a thorough steaming for the last treatment of the day, and leaving the vat covers up over night and during periods of non-use. The hot metal, due to thorough steam treatment, expedites evaporation of moisture and makes for rapid and complete drying. The open vat covers provide the ventilation necessary to keep the vat dry while not in use.

MECHANICAL CARE OF CREAMERY EQUIPMENT

Systematic inspection, timely repairs, and proper care of all equipment, assist in guarding against costly breakdowns, during the flush of the season, serious accidents to personnel and damage to the quality of the product. These precautions likewise make for efficiency of operation and for prolonging the life of the equipment.

Attention to Directions Furnished by Manufacturer.—Most of the major pieces of equipment purchased new, are accompanied by detailed directions from the manufacturer, for installation, operation and care. These directions are usually specific, plain and practical. They constitute valuable information for the guidance of the operator, should be posted in the factory where they are readily accessible to the personnel, and should be followed closely.

Importance of Routine Inspection and Care.—Accidents and sudden breakdowns are largely prevented by the establishment of, and adherence to a routine system of inspection and of

needed care. Some of the equipment needs this daily, some weekly or monthly, and all equipment should receive a general overhauling at least once per year.

Routine of Oiling.—That mechanical equipment needs oiling is self-evident. Rapid wear and tear is often largely the result of lack of attention to lubrication, which in such cases usually escapes proper notice until the damage done by its continued neglect, causes serious operating trouble. In the rush of daily routine work, there is a tendency for the personnel to defer such details that do not absolutely have to be done at a certain time. Attention to lubrication of equipment appears to be one of these details that is readily put off.

The most dependable means of guarding against this tendency and of making sure that all wearing parts are properly lubricated at all times, lies in delegating to the engineer, mechanic, or to some one individual of the factory personnel, the responsibility of making a daily circuit of all equipment with the oil can, replenishing lubricators, turning down grease cups, and seeing to it that all oiling systems are free from obstructions and function freely.

Care of Motors.—Motors used in the creamery, with armament protected from moisture, grease and dirt (preferably of moisture-proof construction), placed level and fastened securely to a firm foundation, suitably wired, properly belted in case of belt drive, and operated under a normal load, require comparatively little attention aside from lubrication. Motors located where the air is clean and dry, may not need overhauling for many years (8 to 10 years). Motors operating in a damp and greasy atmosphere, however, should have attention much oftener. The ideal would be to overhaul and clean them every two years.

The appearance of the motor on the outside is usually a fair criterion of whether it needs taking apart for cleaning the windings. If it is greasy on the outside, grease generally reaches the windings also, as the operating motor draws the air in. Grease soaking into the windings lowers the resistance, so that the motor will not carry its capacity load without danger of burning out.

The condition of the bearings and of the oiling system also needs attention. With the small clearance between rotor and stator, even a slight wear of the lining of the bearing may

cause the rotor to rub on the stator. Worn bearings should be immediately replaced by new ones. The oil rings or other oiling device, should be kept in satisfactory operating condition.

When overhauling the motor, the windings, oiling devices and oil reservoir should be washed with naphtha or gasoline. The windings then should be thoroughly dried preferably over night, then painted with two coats of shellac or with insulating varnish, such as may be obtained from electrical supply houses. The emptied and cleaned oil reservoirs should be refilled to the line marking the required amount of oil and kept so filled.

Motors on equipment, such as churns, vats, pasteurizers, can washers, pumps, etc., that have been in service for a number of years, are best overhauled when such equipment is temporarily out of service.

Care of Ammonia Compressor and Condenser.—The compressor should receive an annual overhauling, checking it for clearance and adjusting the pistons accordingly; taking up on connecting rods, going over all bearings for needed tightening, grinding valves if necessary, cleaning the suction gas strainer, changing the oil and replacing worn parts where needed.

The condenser coils should be cleaned at least once a year, and examined oftener by taking off a return bend from the end of the condenser. The condensers should also receive an occasional purging of air and foul gases, which is essential for maintaining low condenser pressures.

Care of Pumps.—All creamery pumps need inspection and overhauling at reasonable, regular intervals. Cream pumps of the Viking rotary type should be inspected for wabbly shafts and pinions cutting out bearings that may incorporate particles of brass in cream and butter. The worn or defective parts should be replaced by new. If the wear and tear on important parts has been excessively heavy, an entire new assembly may be needed. Or, the pump may be reconditioned at less cost by an efficient overhauling in a machine shop, trueing up rotor and idler, shrinking a new liner into the casing, or building up work shafts and rotors by metallizing. Under extreme conditions of wear it may be necessary, however, to replace the entire head of the cream pump.

In the case of worn brine pumps with piston cylinders, replacement of the cylinder lining will usually recondition the

pump satisfactorily, unless the casing is rusted out around the liner, necessitating replacement of pump.

Care of Can Washer.—The best criterion of the operating efficiency of this important machine is the condition of the cans when they leave the can washer. Their daily inspection provides an effective check-up on the performance of the can washer. In addition there is need of a complete overhauling of the can washer annually, replacing worn parts and making sure that its valves function properly, that its wash water, steam- and rinse water-jets are free from obstructions and deliver full size jets of cleaning and sterilizing medium at full pressure, that the heated air system is operating efficiently and that the can moving mechanism is placing each can squarely over the successive jets. It is important also to check the alkali water feed arrangement, to make sure that the wash water receives a continuous charge of a sufficient amount of alkali to maintain its desired alkalinity.

Care of Vats, Forewarmers, Pasteurizers, Coolers, Cream Strainers, Valves and Fittings.—A thorough annual inspection may reveal the need of replacement of worn driving parts, of rusted out vat nipples (preferably to be replaced by brass nipples), of trueing up coil shafts, renewal of packing in glands, repairs of cracks in seams of liners, covers and around coil stays, retinning of tinned copper surfaces, or retouching of spots of exposed copper, etc. Sanitary tinned copper pipes with copper exposed on inside, should be retinned or replaced by new. Defective cream strainers should be repaired or recovered. Leaky valves in cream, water, steam and brine lines should be ground to a tight fit or replaced by new. Leaky fittings of any kind, in cream, water, steam and brine lines should be eliminated.

Care of Churns and Butter Workers.—A complete overhauling of the driving mechanism and replacement of worn parts is essential before entering upon the flush season. The churn drum also needs inspection in order to locate and tighten loose shelves, replace defective worker rolls and staves, eliminate rusty bolt heads, and replace cracked spy glasses. Defective churn strainers and churn door screens should be repaired.

Care of Packing and Printing Equipment.—The cubes of the cube butter printers should be checked for state of repair,

deformed cubes should be trued up or discarded. Wire cutter heads need to be examined for condition and spacing of wires. Hopper boxes and Archimedean screws should be repaired where needed, conveyor belts and rollers and printing tables need inspection for defects that would jeopardize quality. The driving mechanism of continuous butter cutting machines should be overhauled, trued up, and worn parts replaced.

Care of Scales.—All scales for weighing cream and butter, and the balances used for the Babcock test of cream, and for the moisture test of butter, should be checked daily or oftener for accuracy and sensibility. At reasonable intervals they should be given a general overhauling, examining and cleaning their bearings, replacing worn parts, determining the sensibility of scales and balances and checking weights against standard weights for accuracy.

Care of Insulation.—Insulation on pipes, fittings, tanks, vats, etc. that has become defective, forfeits its purpose as a saver of heat and cold and it leads to rapid corrosion of metal surfaces and to rotting of wood. Low temperature metal surfaces such as ammonia return lines, brine pipes, brine tanks, cold water pipes, etc., when exposed to air, will frost or be wet. In either case the insulation covering will become moisture-soaked, destroying its insulating efficiency and inducing corrosion of the metal.

It is important, therefore, to maintain all insulation in such repair as to retain its snug fit around pipes, or on sides of tanks, avoiding cracking or opening of seams and leaks at joints. In short, insulation should be kept air-tight throughout. The insulation coverings in all parts of the plant need frequent inspection, and any indication of defects, such as broken binding wire, cracks, open seams, etc., should be repaired without delay.

Similar vigilance is needed relative to floor, walls and ceiling in the creamery cold room. Any cracks in the floor or in the finishing coat covering the insulation on walls and ceiling admit air and dampness to the insulation, that will diminish the efficiency of insulation and increase the cost of refrigeration. Such cracks also augment the tendency to mold formation. They should be promptly repaired with a suitable crack-filler or, if necessary, by resurfacing the defective areas.

Creamery Floor and Drain Ditches.—Cracks and holes in the concrete factory floor and drain ditches are enemies of sanitation. They absorb milk remnants and become prolific potential breeding places for germ life. Defective concrete floors soon become a source of foul odors in the creamery. Their satisfactory up-keep makes necessary an efficient inspection to locate the defective spots, followed by the needed repairs, at least once per year.

In the case of large sections of broken down floor, complete renewal is usually the most satisfactory solution. For limited areas and for cracks, prepared concrete floor menders and crack fillers, such as Inlaycrete, or Stonehart cement are preferable, because their special composition makes a better and more permanent bond than ordinary cement. They are somewhat expensive, however, and for patching of holes over an inch deep, they are best used only as a topping. They are very satisfactory for repairs of cracks and worn spots in concrete floors when applied properly, as suggested below for Inlaycrete:

In case of a hole, cut the edges of the defective place vertically to its depth. Then paint the part to be patched with a grout made by mixing a small amount of Inlaycrete with water. Now fill the hole with concrete to within about ¾ inch of the top. When this has "set," a topping of Inlaycrete mixed with a small amount of water to a putty-like consistency, can be put on. Tamp well at the edges of the hole, so as to make bonding more certain.

When patching a crack in the floor, cut down the edges of the crack vertically or wedge shaped to a depth of one-half inch or more and a width of about 1½ inches. Paint the groove with a grout of Inlaycrete and then fill it with the regular mix of the same material.

REFERENCES

1. BIERI, W., Schweiz. Zentralbl. f. Milchw. XX, *12*, 3, (1931).
2. DEMETER, K. J., and CHRISTIANSEN, H. O., Molk. Zeitg. Hildesheim, *55*, 3, (1934).
3. HUNZIKER, O. F., and BEHLMER, H. E., Blue Valley Factory, Chicago (not publ.), (1931-'38).
4. RICE, F. E., and MISCALL, J., J. D. Sc. VI, *4*, 261, (1923).
5. DAVIES, W. L., J. D. Res. *4*, 255, (1933).
6. LAQUE, F. L., and SEARLE, H. E., Intern. Nickel Co., Bul. TS-1, (1937).
7. HUNZIKER, O. F., and HOSMAN, D. FAY, J. D. Sc. I, *4*, 320, (1917).
8. SELIGMAN, R., Proc. World's D. Congr. II, 1211, (1923).
9. MOHR, W., OSTERBURG, GUERTLER, and LIEPUS, Reichskurator. f. Techn. in d. Landw., Berlin, (1930).

10. HUNZIKER, O. F., CORDES, W. A., and BEHLMER, H. F., Blue Valley Res. Labs. (not publ.), (1938).
11. MOHR, W., and SCHULZ, Milchw. Zeitg. 26a-28a, 1037, (1930).
12. BRENNERT, S., Intern. Tin Res. and Dev. Council Tech. Publ. Ser. D 2, (1935).
13. ROADHOUSE, C. L., and HENDERSON, J. L., J. D. Sc. XXII, *6*, 413, (1939).

CHAPTER V.

FACTORY SANITATION

In addition to consideration of the sanitary suitableness of materials used in the construction of creamery equipment, which was discussed in the previous chapter, creamery sanitation has to do with such important factors as accessibility of equipment, sanitary care of equipment and building, personal hygiene of employees, choice and proper use of washing and sterilizing compounds, protection of plant, equipment, and product from flies, insects and rodents, etc.

Accessibility of Equipment.—The sanitary condition of any piece of creamery equipment depends to a large extent on the accessibility for cleaning of all parts that come in contact with milk, cream, and butter. There is probably no operation in the creamery less fool-proof than that of cleaning the equipment. This work still must be done by hand and in its performance the personal element, the human factor, plays a deciding rôle. "Cleaning up" is distasteful to the average employee and, unless the parts that need cleaning are readily accessible, this work is often not done properly and factory sanitation suffers. Accessibility of creamery equipment is dependent on both, the construction and the arrangement of the equipment.

Great strides have been made within recent years by equipment manufacturers in the direction of improving and perfecting the sanitary phase of creamery machinery. Vat linings and covers are sealed in a manner that prevents the possibility of cream seeping through between lining and insulation. Heating surfaces are made more accessible for cleaning and retinning. Pumps and sanitary fittings have been simplified in construction for ready disassembling. Glands and their packing on the inside of the vat have been eliminated and placed outside so as to be more accessible for adjustment, cleaning, and renewal of packing. Flush valves are provided for vat pasteurizers to insure complete pasteurization of all the cream in the vat. Churn rolls and butter cutters have been made more accessible. Insanitary cork gaskets have been eliminated from churn door frames, etc.

Satisfactory accessibility for ready cleaning does not mean extravagance of space. Compactness of arrangement of the equipment is desirable, both for economic and for sanitary operating efficiency, provided that each piece of equipment is so placed and its connections are so organized, as to afford ready access for repairs, and for daily cleaning and dissembling where necessary.

Sanitary Care of Equipment.—Too much emphasis cannot be placed on the importance of daily thorough cleaning and sterilizing of all equipment. This is a detail which is so often neglected "in spots." That the plant should look clean and neat is obvious. The natural pride of the personnel, or at least of the superintendent, is usually sufficient to insure sanitation to that extent. However, the mere general appearance is not neccessarily a guarantee of cleanliness in all details. Plant sanitation means more than just good general appearance. It means that all parts of equipment have been thoroughly cleaned and sterilized, that cream pumps have been taken apart, and sanitary lines disassembled for complete removal of all remnants of cream: that forewarmers, strainers, pasteurizers, vats, butter culture tanks, churns, printing equipment, and all connections, fittings and accessories coming in contact with the product, have received such treatment as to remove from them all curd, grease, and other milk constituents and foreign matter, and that they are clean and sterile; it means the daily scrubbing of floors and drains, the cleaning of drain traps, and the use of chemical disinfectants when necessary.

This should be done each day at the conclusion of the manufacturing work. The entire line should be flushed with an abundance of hot water and steamed thoroughly again the next day before the cream is permitted to circulate. Similar precautions are needed in the print room before the butter is allowed to touch the equipment. For details on cleaning and sterilizing wooden equipment such as the churn drum and butter packing equipment see Chapter IV on "Wood in Creamery Equipment."

Tinned copper surfaces, such as in forewarmers, pasteurizing vats, starter vats and sanitary cream lines should be retinned as soon as they show considerable areas of bare copper. Walls and ceilings in creamery and print room should be washed

at least once per year or oftener and repainted when necessary. Cold rooms should be kept free from mold by frequent treatment with whitewash or other suitable disinfectant, or they may be painted, preferably with mold-proof paint. Waste and rubbish should be removed daily; they attract insects, vermin and rodents. The screens should be kept intact and floors, walls, ceiling and roof should be kept in good repair.

The sanitary upkeep of equipment and building has to do with a multitude of details that require daily attention, conscientious work and above all, intelligent and efficient supervision.

Personal Hygiene and Cleanliness of Employees.—The state of sanitation and cleanliness of the creamery is usually a fairly true mirror of the personal standard of hygiene and cleanliness of the employees. Too much emphasis cannot be placed on the need, on the part of the creamery personnel, of cultivating and practicing habits that insure the observation of established precepts of sanitation in the handling of products intended for human consumption.

In addition to good health and freedom from skin sores, personal hygiene means cleanly personal habits, clean hands and clothing, abstinence from the use of tobacco in any form while at work, handling cream and butter with due regard to protection against contamination, avoidance of contact of the bare hands with cream and butter, and conscientious performance of all cleaning operations that have to do with creamery supplies, equipment and building.

In order to further the cause of personal health, hygiene and cleanliness, there should be provided adequate facilities, such as properly equipped toilet and bath provisions, wash basins where needed in the factory, clean suits and clean gloves, proper tools for tasting cream and butter, suitable means for disposing of waste and rubbish, efficient ventilation, etc. These various facilities are fully discussed in the chapters dealing with the respective phases of creamery construction, equipment, and operation.

WASHING POWDERS

Mission of Washing Compounds.—The efficient cleansing of the milk side of creamery equipment requires the use of a suitable washing compound. Milk and milk products, in their

original state of colloidal condition, emulsion or solution, possess definite adhesive properties that cause them to adhere to and form a film on the surfaces with which they come in contact. This property of adhesion is further intensified under conditions that disturb their complex colloidal system, such as when acted upon by acid or by heat. Adherence then becomes more tenacious and removal more difficult.

Wetting Power of Alkaline Cleaners.—The milk product deposit can be removed, if a film of liquid can be forced between it and the surface to which it adheres. Alkaline solutions lower the surface tension and thereby have the property of forming emulsions with fats, that enable the liquid to wet the surface and to remove the deposit.

Protein-Dissolving Power of Alkaline Cleaners.—The ingredients contained in the milk deposit are principally fat, protein and mineral constituents. The first important requirement and function of a satisfactory washing powder lies in its power to dissolve protein material, because it is preeminently the protein deposit that imprisons the other milk constituents contained in the deposit. Solution of the protein assists in liberating the fat and mineral constituents and in making the fat available for emulsification and removal.

Fat-Emulsifying Power of Alkaline Cleaners.—The alkali of the cleaning compound facilitates removal of the fat from the surfaces to which it adheres, even when no longer held by the protein, by reason of the emulsifying effect of alkaline solutions on fat, lowering the interfacial tension between oil and water. The resulting alkali-fat-water emulsion provides a surface film that is miscible with water and therefore readily removed. The alkali may also react with free fatty acids, if any are present, forming soap. In the absence of rancidity, however, saponification appears unlikely under the usual conditions incident to the washing operation, but may occur in the presence of strong alkalis combined with high temperature (boiling) of the washing solution.

Water-Softening Power of Alkaline Cleaners.—In addition, the satisfactory performance of a cleaning compound requires that it be capable of softening the water without throwing down the hardness in a manner to aggravate the milkstone problem,

or to cause precipitation of objectionably gummy and sticky material. Since the type of hardness and its response to different washing compounds vary with the water available, no one washing powder may be expected to be a good water softener of every type of water. In case of unsatisfactory results, the difficulty is usually overcome by modifying the available washing solution by the addition to it of a small amount of another alkali, more suitable for the particular water available.

Other Properties of Alkaline Cleaners.—The washing compound should be of a character that will not excessively attack the metal surfaces on which it is used. Furthermore, its cost in relation to its strength is a factor that enters into the problem of economy of operation. Other properties that are usually enumerated in the consideration of washing compounds, such as solubility, washing power, rinsing power, deflocculation, ability to maintain its strength, buffer action, etc., are either covered by the above brief general classification of desirable properties, or deal with more purely theoretical considerations, or are otherwise of negligible significance only, with reference to this discussion.

In general, hot washing solutions are more effective in removing milk product deposits than cold. However, excessive heat is a hindrance to the cleansing effect, tending to precipitate casein and to cause gummy deposits to pack harder onto the metal surface. Philips and co-workers[1] report that up to 140° F, the hotter the washing solution the better, as regards cleaning.

Kinds of Washing Compounds.—Many of the commercial washing powders are mixtures of two or more types of alkali compounds. The washing compounds available for creamery use may be conveniently grouped according to general types, as follows:

Soap powders
Neutral or modified sodas
Causticized sodas
Trisodium phosphates
Sodium metasilicates
Detergents or scouring powders
Milkstone removers
Cleaners containing disinfectants

Soap Powders.—Soaps are understood to be alkaline salts of fatty acids. The alkali, caustic soda, neutralizes the fatty acids and saponifies the glycerides in the oils or fats from which the soap is made. The substance formed as the result of these reactions is soap which no longer contains caustic soda.

Soap powders have excellent emulsifying properties, consisting themselves of an alkaline emulsion in fat. They are, therefore, readily miscible with fatty material and useful in removing fatty films. They are harmless to metals and to the hands of the operator. They are unsuitable as cleaners in the presence of hard water, however, because their limited alkali strength is practically all dissipated by the calcium and magnesium salts contained in hard water, which they fail to completely precipitate. The salts left in solution combine with the fat of the soap into gummy and sticky deposits that are difficult to remove from the surfaces to which they tenaciously adhere.

At best, solutions of soap compounds rinse poorly and tend to leave a film on the cleaned surface that readily harbors bacteria. As a group, they are not desirable cleaners of the milk side of creamery equipment, but are suitable for washing woodwork, scrubbing floors, etc. In combination with stronger alkalies that supplement the alkali deficiency of soap, their function as cleansers may be materially improved.

Neutral Sodas or Modified Sodas.—These sodas have found wide use as dairy cleaners. They are readily soluble, of low causticity and, because of their mild action on the skin, are well suited for washing by hand. According to Barnum, Lucas and Hartsuch[2] their causticity in 1% solutions is equivalent to a pH of 10.0.

The neutral sodas are not sufficiently strong in alkalinity to be efficient cleansers of heating surfaces, such as pasteurizers, but are particularly suitable for use in the washing of churn drums to preserve the wood which tends to become soft and sticky in the presence of more highly caustic washing powders. Neutral sodas contain varying mixtures of soda ash (sodium carbonate) and baking soda (sodium bicarbonate). The presence of the bicarbonate insures absence of caustic alkali. Their composition usually consists of about 45 to 60% of soda ash and 25 to 35% of baking soda, the remainder being principally

water. The mixture is either mechanical or chemical. The chemical mixture is technically known as sodium sesquicarbonate. They are less corrosive to metals than straight soda ash, but attack aluminum severly and have some action on tin and zinc.

This group embraces a large number of commercial washing powders, such as Wyandotte Cleaner and Cleanser, Mathieson Virginia Soda, Solvay Super Cleanser, Swifts Dairyland Soda, Benner Superior Washing Soda, Cudahy's Cleaner and Cleanser, Diamond Soda Crystals.

Soda Ash Cleaners.—These washing compounds consist largely of straight sodium carbonate (Na_2CO_3). Soda ash contains about 99% sodium carbonate, consisting of approximately 58% sodium dioxide (Na_2O). It is evaluated in terms of its sodium dioxide content, hence the usual term 58% soda ash, applied to standard soda ash, expresses the percentage of sodium dioxide it contains. The remainder of the composition of soda ash is principally carbon dioxide, except in the case of sal soda ($Na_2CO_3 . 10H_2O$) in which the sodium carbonate is combined with 10 molecules of water of crystallization. Sal soda contains over 60% of water.

The causticity of standard soda ash is considerably greater than that of the modified sodas. Its pH is reported to be 10.6. It is a mild alkali, however, and unless used in concentrated solution, it is not unduly severe on the hands, nor on tinned surfaces. Soda ash is an efficient remover of films of fat and of protein material, and has the further advantage of being the cheapest washing compound available for creamery use.

It is likewise an excellent water softener. It is in fact the basis of practically all water softening compounds. For creamery purposes, however, the water-softening effect of soda ash is often objectionable, because of the type of precipitate it yields. Instead of producing a soft, flocculent material, it precipitates the calcium salts in the form of a fine granular chalk-like mass of calcium carbonate that adheres to metal surfaces and aggravates the building up of milkstone. This difficulty in the case of hard water may be readily corrected, however, by using soda ash and trisodium phosphate together. According to the results of Tuckey,[3] and of Phillips and co-workers,[1] proportions of from two parts of soda ash and one part of trisodium

phosphate to equal parts of each, change the objectionable chalk-like white film to a satisfactory flocculent precipitate. Mixtures of equal parts of the two compounds expedite the formation of the flocculent precipitate.

Soda ash is suitable for the cleaning of all creamery equipment. To this group of cleaners belong Diamond Soda Ash, Solvay Fluff, Church and White Pioneer Cleaner, Sal Soda, etc.

Causticized Sodas or Special Alkalies.—The cleaners of this group differ from the previous ones in that the special alkalies contain from about 30-50% of caustic soda, or soda lye (NaOH), mixed with soda ash. They are strongly caustic. According to Barnum and co-workers,[2] 1% solutions have a pH of 12.6. They should be used for machine washing only. They severely attack tin, copper, galvanized iron, iron, aluminum and glass enamel, but do not corrode nickel, white metal, stainless steel and chrome nickel alloy. They should not be used on tinned surfaces nor glass enamel, because they destroy the tin coating rapidly, and they shorten the life of glass enamel. They are not suitable for use in washing cream cans, although they are extensively used in can washing machines. To this group belongs Wyandotte Alkali Special, Dominion Machine Alkali, Solvay Super Alkali Nos. 3 and 4, Swift's Keystone, Diamond Special Alkalies.

Trisodium Phosphate Cleaners.—Trisodium phosphate ($Na_3PO_4 \cdot 12H_2O$) has found extensive use as a cleaner of creamery equipment. It is a readily soluble, mildly alkaline salt, with a pH of 11.9 in 0.5% solutions and of 12. in 1% solutions. According to Smither,[4] it contains about 56% of combined water. It is an excellent water softener and emulsifier. Its protein dissolving power, while apparently not ranking high in theoretical classifications, has proved highly satisfactory in practical use. In fact, trisodium phosphate is one of the most effective cleaners for routine use on heating surfaces, such as pasteurizers. It is outstanding in its ability to remove curdy material cooked on to metal surfaces. This action appears to be assisted by the fact that when the trisodium phosphate is dissolved in water it is partly hydrolized or changed to disodium phosphate and caustic soda. Its action on tin is somewhat less severe than that of soda ash and is almost completely negative in the presence of 5% sodium dichromate. It corrodes and tarnishes aluminum.

Trisodium phosphate, either alone, or in combination with

other cleaners, is suitable for every type of creamery equipment, except the interior of the wooden churn drum, and it is especially effective for cleaning pasteurizers. It has been found particularly suitable when used in combination with soda ash. Phillips, Mack and Frandsen[1] recommend a mixture of 60% soda ash and 40% trisodium phosphate. In addition to its availability as commercial trisodium phosphate, it is the basic ingredient of numerous commercial cleansers which may contain in addition soda ash, caustic soda, borates, etc. Representatives of trisodium phosphate cleaners are the well-known Oakite products, also O. G. Crystals, Climaline, Westolite, Kristlite, Chemical Cleaner, and Kolo No. 10.

Sodium Metasilicates ($Na_2O.\ SiO_25H_2O$).—Sodium metasilicate represents a compound of sodium oxide and silica, mixed at a ratio that makes it a very effective cleaner. It is an efficient water softener. Unlike certain other alkalies which form a dense, gummy, adhering precipitate with the hardness in water, the precipitate formed by metasilicate is soft and flocculent, and remains more readily in suspension.

It is a good solvent of protein material and in addition possesses colloidal properties, due to the presence of silicon ions, protecting such metals as tin and aluminum against damaging corrosion. It is readily soluble in hot and cold water and rinses easily. Its pronounced buffer action causes the metasilicate to retain its alkali strength. It is satisfactorily high in pH value, ranging from pH 11.33 to 12.32, in concentrations of 0.01 to 1.0%, respectively.

Sodium metasilicate has proved suitable for use in every type of creamery equipment, either alone or in combination with other cleaners, such as soda ash and trisodium phosphate, excepting for the interior of wooden churn drums. Representative commercial metasilicate cleaners are Metso, Standard Sodium Metasilicate, Metso 22.

Detergents or Scouring Powders.—Technically, any compound that has cleansing properties is a detergent. All the cleaners enumerated above are detergents. In creamery parlance, however, the name detergent is usually meant to apply to cleaners that contain, in addition to their chemical cleaning ingredients, such as alkalies, an insoluble abrasive substance. These so-called detergents are used chiefly because of their

specific scouring properties. Detergents of this group are, in fact, scouring powders. A well-known representative is Wyandotte Detergent. The abrasive of scouring powders usually consists of volcanic ash, powdered pumice stone, marble, feldspar, or quartz. Scouring powders may contain as high as 75% abrasive material or more, mixed with soap and soda ash. While scouring powders are effective removers of hard deposits from metal surfaces, such as milkstone, they obviously are abrasive also to soft metal surfaces, such as tin. If applied to tin-coated surfaces they should be used with caution, otherwise the tin coating will soon disappear. They serve many useful purposes in the creamery, however, and are especially suitable for cleaning painted surfaces on walls and ceilings and exterior surfaces on equipment.

Concentration of Washing Powder Solutions.—The strength of the washing solution used has a direct bearing on the efficiency and economy of washing operations in the creamery. The concentration of the washing solution should be sufficient to accomplish efficient cleaning. Concentrations in excess of this are of no added benefit. They are a wasteful use of washing powder and may be damaging to equipment. The general tendency on the part of the average personnel lies in the direction of using too much washing powder. It is wisdom to provide a tin cup or other suitable measure, of a size that will hold the correct amount of washing powder required for use in a given number of gallons of water.

Prepared Washing Compounds.—The most suitable strength of washing powder solution will vary somewhat with the character of washing powder and with the exact purpose for which it is used. Some of the manufacturers of prepared mixtures of washing powders have given extensive study to the optimum concentration of washing solutions made from their powders, and are in a position to give specific directions for the most effective and most economical use of their cleaner. Such directions are helpful and should be followed closely by the user for his own best interests.

Amount of Washing Powder to Use.—In the absence of prepared mixtures, such as when using the simple alkali compounds, such as soda ash, trisodium phosphate, sodium meta-

silicate, etc., or where the creamery is preparing its own mixture from these simple compounds, it is generally satisfactory and economical to use enough powder to have the washing solution contain 0.5% of the single powder or of the mixture of powders. The choice of powder or of mixture of powders may then be governed by the character of the available water and according to type of equipment to be cleaned.

CHOICE OF WASHING POWDERS FOR DIFFERENT PURPOSES

For Wooden Equipment, Such as Interior of Churn Drum, Packing and Printing Equipment, highly caustic alkalies should not be used. They tend to soften and destroy the grain of the wood, shortening the life of such equipment and increasing its tendency to stickiness. For this type of equipment the compounds of lesser causticity, such as neutral sodas and soda ash are most suitable.

For All Metal Surfaces, Such as Forewarmers, Pasteurizers, Cream Vats, Culture Tanks, Cream Coolers, Cream Pumps, Pipe Lines, Cream Strainers, Machine Washed Cream Cans, etc., washing powders of moderately high causticity are needed. This refers to soda ash, trisodium phosphate, sodium metasilicate, or mixtures of two or more of these compounds. For pasteurizers in particular, trisodium phosphate or compounds containing this product are especially suitable.

For Floors, soap powders, as well as neutral sodas, soda ash, etc., are suitable. The cleaning of floors is most effectively done by first wetting the floor with clear water, then sprinkling the dry powder over it, followed by a thorough scrubbing and a complete rinse with clear water. The often observed practice of using the acid from the cream test bottles for scouring concrete or tile floors is exceedingly destructive to the floor. It eats the lime out of the concrete and deteriorates the floor rapidly.

For Painted Woodwork, Other Painted Surfaces and for Exterior of Equipment the use of a good scouring powder is recommended. The powder is sprinkled on a moistened rag and the surface scoured with this rag.

For Can Washing Machines trisodium phosphate, or sodium metasilicate, or prepared mixtures containing one or both of these compounds are most suitable. Special alkalies are very effective from the standpoint of cleaning, but they are destructive to the tin coating, causing early and profuse rusting of the base metal.

For Babcock Test Bottles and Other Glassware any one of the cleaning compounds is suitable, provided that the bottles are first thoroughly rinsed with clear water to free them completely from all acid before the alkali is added. In case a tenacious scum has accumulated on the glass surface a 50:50 mixture of sulphuric acid and water (about 15cc. of the mixture per bottle) will assist in dissolving the scum. They should then be rinsed with clear water followed by the use of washing powder.

For Aluminum Equipment use solutions of 0.5% soda ash to which has been added 0.05% sodium silicate. If caustic soda is used in strengths ranging from 0.1 to 1.0% caustic, add 0.5 to 5.0% sodium silicate, according to strength of caustic soda solution. Or, use an especially prepared aluminum cleaner, following the manufacturer's directions that accompany the cleaner, such as Oakite Aviation Cleaner, J. B. Ford Co. Cherokee Cleaner, Solvay Aluminum Cleanser.

Milk Stone Removers.—The presence of milk stone on metal surfaces of heating coils in pasteurizing vats, in flash pasteurizers, and in pipes conducting uncooled pasteurized cream, is a common occurrence in the creamery. The coating of milk stone on metal surfaces consists principally of protein, fat and mineral constituents. Tucky,[3] and Ruehe[5] showed that the percentage of these ingredients varies within wide limits and that the mineral portion consists largely of calcium acid phosphate and a lesser amount of magnesium phosphate. When milk or cream is heated, these soluble minerals change to insoluble salts, become enmeshed, together with some fat, in the protein material which ties them firmly to the heating surface. If allowed to accumulate, the milk stone coating acts as an effective insulation on the heating surface, retarding heat transfer. Milk stone provides a potential breeding place for micro-organisms.

Causes of Milk Stone.—The major factors that encourage the formation of milk stone deposits are: high temperature heating surface, faulty treatment of hard water used for washing, and delayed washing of equipment.

In the creamery the initial, and probably the dominant, cause of milk stone formation is attributable to the usually wide difference between the temperature of heating medium used in pasteurization, the water or steam, and the pasteurizing temperature of the milk product. The higher the temperature of the heating surface above that of the milk product, the greater the tendency for milk stone trouble. Milk stone formation can be materially retarded by such design and operation of pasteurizing equipment, as will make unnecessary the use of the heating medium at a temperature greatly in excess of the temperature to which the milk product is heated. Unfortunately vat pasteurization using the helical coil, and flash pasteurization with the steam jacketed pasteurizer, do not readily lend themselves to the maintenance of a narrow temperature range between heating medium and cream, without excessive prolongation of the pasteurizing process.

It was shown in earlier paragraphs that in the case of certain types of hard water, when using soda ash as washing powder, the calcium salts are thrown down in the form of a fine granular chalk-like precipitate that materially adds to the building up of milk stone deposits. It was further pointed out that this objectionable precipitate can be avoided by using trisodium phosphate with the soda ash.

Prevention of Milk Stone.—The method of washing the equipment plays a large part in the presence or absence of milk stone on metallic surfaces. As long as the fresh layer of protein-fat-mineral deposit is still wet, it can be removed fairly readily and completely by ordinary methods of cleaning. In the case of the pasteurizing vat, for instance, milk stone accumulations can be prevented with certainty and the coil kept bright and shining indefinitely, by the following procedure:

After the vat has been emptied and rinsed, wash it before the metal surface has had opportunity to dry, i.e., while it is still wet. If the factory routine does not permit of immediate washing, fill the vat one-third to one-half full with lukewarm water (not over 110° F.), and allow the coil to revolve with cover

down, until ready to wash. For washing, apply cloth or brush with a small amount of a good scouring powder to the revolving coil to remove coating of milk deposit. Then wash in the usual way, rinse with cold water, and steam. The scouring powder, when used lightly on the coil covered with soft wet milk deposit, has no objectionable abrasive effect, not even on the tin-coated surface, and the coil so treated retains its bright metallic luster. The secret of successful prevention of milk stone lies in never allowing the milk deposit to dry on the metal surface.

Removal of Milk Stone.—When the milk coating has been allowed to dry, no abrasive of any kind is capable of removing it without damage to the metal surface. In the case of tinned copper, any attempt to remove the dried-on milk stone with an abrasive will also remove the tin coating. The only effective means of removing accumulations of dried-on milk stone is to wash the vat in a weak alkaline solution in the usual way, followed by treatment with a weak acid. This may be done conveniently by the following procedure:

Use an organic acid in preference to mineral acid, to minimize damaging attack on the metal. Fill the vat with enough water for the lower part of the coil to dip into it. Add 0.5% tartaric acid crystals (one-half pound per 12 gallons of water). Heat the solution to approximately 150° F. with the revolving coil. Run the coil for about 30 minutes in this heated acid solution. Then empty and flush thoroughly with clean water.

There are now available also prepared milk stone removers, such as: Oakite Milk Stone Remover, and Solvay Casein and Milk Stone Solvent, Diversey Peptex, and Diversey Dicoloid. These prepared milk stone removers are generally accompanied by specific directions for use. For best results the directions provided by the respective manufacturers should be followed accurately.

CHEMICAL STERILIZERS

Disinfecting Powers of Alkaline Washing Powders.—The hot washing powder solutions themselves possess definite germicidal properties. Phillips and co-workers,[1] who made a comparative study of the efficiency of such washing compounds as sodium carbonate (soda ash), sodium hydroxide (caustice soda), and trisodium phosphate, using 0.6% solutions of each com-

pound, respectively, found that in these concentrations which are ordinarily employed in commercial usage, these washing powders act as disinfectants to such a degree as to make the washing solution sterile. They further reported that while a temperature of 140° F. is about the maximum that is practicable to use without causing objectionable precipitation of protein, the germicidal efficiency of washing solutions diminishes at lower temperatures and is much reduced below 95° F. The bactericidal effect of washing powders has been demonstrated also by the work of Mudge & Lawler,[6] Levin, Peterson and Buchanan,[7] Levine, Toulouse and Buchanan,[8] and Myers.[9]

Cleaners Containing Disinfectants.—Some of the commercially prepared washing compounds contain, in addition to alkaline cleaning elements, specific chemical sterilizers, such as hypochlorite, or chloramine products. Their disinfecting property is about equal to that of commercial hypochlorite disinfectants. The fact that the presence of organic matter dissipates the chlorine, and that equipment should be clean and free from organic matter, such as remnants of milk products, before the chlorine reaches it, raises the pertinent question as to the sterilizing efficiency for creamery use, of combined cleaners and sterilizers when applied to unwashed equipment.

When used in connection with metal and glass enameled tanks for storage and transportation of milk and fluid milk products, however, and when these tanks are rinsed down thoroughly with water immediately after use, these combination cleaners and sterilizers have shown marked germ-killing efficiency and have proven labor savers. Likewise on the dairy farm, where steam is generally not available, these combined cleansers and disinfectants have unquestionable merit and their use for cleansing milk utensils, separator bowls, and the like, should be of material assistance in the direction of improving the quality of cream, insofar as improvement depends on the cleanness of milk utensils. To this group of cleansers belong the products kown as Diversol, Klen-o-Cide and Oakite Bactericide.

Disinfectants.—In the creamery the routine of sterilizing the milk side of equipment is predominantly done with hot water, or steam. There is an increasing trend toward the use

of chemical sterilizers, however. Recourse to chemical germicides is especially helpful in the case of equipment and places that cannot be effectively sterilized, or economically reached with steam, such as brine-filled surface coolers and internal tube coolers, long pipe lines, conveyor belts and tables in printroom, platforms, drain ditches and traps, sewers, ventilating hoods and flues, floors, walls and ceiling in creamery proper, in print room and in cold rooms, also for treating the water that is used for rinsing down vats at the time of filling the churns, for washing butter and for moisture control work, and for a time-and fuel-saving churn-rinse in the morning, etc.

Of the chemical sterilizers available, the chlorine compounds have been found highly suitable and are almost exclusively used for milk plant and creamery work. Formalin is also very effective and, when diluted at the rate of approximately four ounces to one gallon of water, provides an efficient spray for the destruction of molds on walls and ceilings. Its safe handling under average creamery conditions is somewhat of a problem, however, and its penetrating pungent odor jeopardizes the dairy product.

Chlorine Disinfectants.—Chlorine compounds, such as are used as disinfectants, are active germicides. When used in proper strength they are dependable sterilizers. Their odors are not objectionable. When used properly and in normal amounts they have no damaging effect on the flavor of the dairy product, and they are non-toxic.

Chlorine sterilizers are of two general types; namely, inorganic compounds and organic compounds. To the inorganic compounds belong the hypochlorites, such as hypochlorite of calcium and hypochlorite of sodium (Dakins solution). The organic chlorine compounds are represented by the chloramines, such as chloramine-T.

The germicidal effect of chlorine compounds appears to be two-fold, namely, the available chlorine liberates oxygen that destroys organic matter and germ life, and the presence of hydrochlorous acid which hastens and intensifies the reaction of the chlorine. In the case of hypochlorites, at least a portion of the chlorine is present in the form of hydrochlorous acid. The disinfecting powers of chlorine compounds are, therefore, increased with an increase in available chlorine, and germ destruc-

tion is expedited by low alkalinity that permits of the presence of undissociated hydrochlorous acid.

The single purpose hypochlorites that are intended exclusively for sterilizing purposes and not as cleaners, and that are, therefore, not highly buffered with alkalies, are quick-acting and only slightly stabilized. Their dilutions for use surrender their available chlorine quickly, their action is intense while it lasts, their germ destruction is high, and their corrosive action on metals, such as tinned copper, tinned iron, galvanized iron, etc., is correspondingly severe. Because of their quick action and their relatively high germ-killing efficiency upon short period of contact, these hypochlorites are highly suitable for use in the creamery. To this group belong the home-made chlorine solutions prepared from bleaching powder or by passing chlorine gas through water, also such commercially prepared hypochlorites as B. K. (Bacilli-Kill), Germifectant, and Chlorofectant. They are usually available in liquid form, and are accompanied by information as to percentage of available chlorine, and directions for use.

Chloramine-T products are usually sold in powder form. These products are comparatively stable. They surrender the available chlorine more slowly than the hypochlorites and their efficiency as germicides requires longer contact with the surface to be sterilized. To this group belong such commercial chlorine sterilizers as Santamine, Sterilac, Wyandotte Sterilizer, Klen-O-Cidex, Da-Klor-Omin Chlorine Powder.

While the products in each of the above groups have certain fundamental group characteristics with reference to their germicidal effect and metallic corrosion, individual preparations belonging to one and the same group may differ considerably in their action, even when their dilutions are adjusted to the same chlorine content. Commercial preparations are usually accompanied by full directions for use for different purposes. For dependable results these directions should be followed.

The suitable strength of chlorine solutions ready for use for creamery purposes may vary from about 25 p.p.m. to 200 p.p.m., according to the purpose for which they are used. The following schedule has been found suitable.

For metal surfaces such as for cream coolers, vats, pipe lines, use 100 p.p.m. of chlorine. This treatment is preferably

given at the beginning of the day, just before allowing the milk or cream to circulate. If used at the end of the day's work, the equipment should be flushed with clean water after the chlorine treatment, in order to avoid damaging corrosion, and jeopardy to the dairy product handled the next day.

For churn drum in the morning, use 150 p.p.m. of chlorine, adding about one quart of 3% chlorine solution to 50 gallons of cold water in the churn and revolving for 15 minutes. This treatment eliminates the necessity of scalding the churn before use in the morning. By thus chlorinating the cold water the sterilizing and chilling of the churn is done in one operation.

In the case of water of doubtful purity, for the water used for washing the butter, for rinsing the cream out of the vat into the churn, and for use in moisture control, use 25 p.p.m. of chlorine. For the above purpose the chlorine solution should be added to the water about 30 minutes before use, in order to give the chlorine ample time for its sterilizing action on the water. Add one pint of 3% chlorine solution to 150 gals. of water.

For soaking parchment wraps for unsalted butter, use 100 p.p.m. of chlorine. Use ½ ounce of 3% chlorine solution in 1 gal. of water.

For milk and cream shipping cans chlorine treatment is not recommended. Sterilization by heat, using hot water, steam and heated air, is preferable. The can is made of tinned steel, which is severely attacked by chlorine products. If the can were given a chlorine rinse followed by water, exposure to the sterilizing action in the can washer would probably average 15 seconds or less. This would not seriously affect the tin, but it is too short a time to accomplish efficient germ destruction. The cream can flora is highly resistant to germicides. If the chlorine rinse were the final treatment in the can washer, the remnants of chlorine solution (containing the highly corrosive hydrochlorous acid), left in the can until it is again filled with milk or cream, would destroy the tin and cause profuse rusting of the steel. Such cans would rapidly deteriorate and would constitute a constant menace to the quality of the butter. Chlorine treatment of tinned steel cans should be avoided.

Temperature of Chlorine Solution.—One of the dominating advantages of the use of chemical sterilizers is that of economy of fuel. They are effective at ordinary temperatures. In addition, the heating of the chlorine solution is inadvisable for other reasons. Heat hastens the liberation of the chlorine. Especially in the hypochlorites, the loosely held chlorine, when the solution is heated above lukewarm temperature, escapes so rapidly that there is danger of dissipating the available chlorine, before the solution has made proper contact with the surfaces to be sterilized. The practice prevailing in some plants to heat the chlorine solution in a vat to around 180° F. and then flush the system with it, is of doubtful merit. Most of the available chlorine escapes into the air before circulation through the system materializes, its germ-killing action is largely lost and the sterilizing effect, if there is any, is mainly due to the high temperature. Clear water at the same temperature would be almost equally effective. The temperature of hypochlorite solutions should not be higher than lukewarm. These solutions are effective at any temperature of unheated water.

KEEPING INSECTS AND RODENTS OUT OF THE CREAMERY.

Combating the Fly Pest.—The fly is a menace to the creamery. Its breeding places, sources of food and habits are associated with insanitation and filth. It is a prolific carrier of micro-organisms characteristic of such sources. Its own habits of life are filthy, it may become and often is a carrier of disease germs, and its larvae, the maggots, are capable of living in butter.

Dairy products emit odors which attract the fly. The first essential in successful efforts to keep flies out of the creamery is therefore, order, cleanliness and absence of rubbish on the outside of the factory. Remnants of spilled milk and cream, the presence of unwashed cream cans, and the accumulation of rubbish in the form of creamery waste at or near doors and windows, invite hordes of flies, some of which will surely infest the interior. The spraying of disinfectants such as borax on receiving platform, at buttermilk delivery pipe, and wherever milk and cream remnants may collect, will materially assist in minimizing the fly pest.

The need of efficient screening of all windows and doors to

keep flies out is obvious. The use of electric screens in windows and especially in screen doors that are opened frequently in the course of the day's operation, and of electric fly traps in the factory, is of great help. Some of the electric screen manufacturing firms survey the needs of the creamery, recommend the most effective distribution of electric screens for windows and doors, and guarantee elimination of flies from the manufacturing rooms, if screened according to their recommendations.

Flies prefer light to darkness. They gravitate towards the light and shun the dark places. In one-story creameries, with skylight and shaded windows, the flies migrate toward the skylight and thus become relatively harmless. In general, the shading of windows during fly time is of help in keeping the flies away from equipment and product. Flies shun severe drafts. The operation of a large fan with blower flue terminating over the door where milk or cream are received, assists in keeping the flies from entering through the opened screen door.

With consistent planning of systematic fly combatment and intelligent cooperation on the part of the creamery personnel, the fly pest can usually be reduced to negligible proportions and may be eliminated entirely.

Cock Roaches.—The cockroach is a persistent nuisance in the creamery. His choice breeding habitat is warm places in the plant, such as along concealed hot water and steam pipes. He comes out in the open at night from cracks in walls, partitions, floors, and coverings of equipment and pipe lines. He is an exasperating visitor for the rapidity with which he multiplies, and for his skill in evading extermination, and he is a disgusting form of insect life, because of his voracious and omnivorous habits, and the damage he does to any food product that he touches.

There are numerous roach powders and liquid roach sprays that destroy the cockroach. The difficulty, however, lies in reaching this beetle effectively. Successful extermination requires determined and persistent effort. Each application of spray should extend over the entire factory, using a spray sufficiently powerful to effectively penetrate into the cracks from which the roaches emanate and to go over all the cracks in one treatment. This usually causes them to disappear for some time. Then, as soon as there is evidence of their return, the treatment

should be repeated. By a persistent follow-up, it is possible to eliminate the roaches to a large extent, but they almost invariably return upon prolonged absence of treatment.

Avoiding concealed steam and hot water pipes and keeping pipe coverings, etc., intact and properly sealed, is of fundamental assistance in limiting potential breeding places for roaches.

Ants.—While invasion of the creamery with ants is not a common occurrence, there are occasions when their appearance becomes a problem. They are readily exterminated by baiting the places of their appearance with a sweet syrup containing metallic arsenic. The theory is that the ants carry the poison back to their nest, poisoning the queen, after which they desert the place. A few applications of this poison usually cause them to disappear completely. Rubbish attracts ants. Freedom from its accumulations assists in keeping ants out of the factory.

Termites.—In certain sections of the country termite invasion of buildings is a constant menace. This occasionally also involves the creamery. Termites are winged, white insects resembling ants. They are closely related to the Blattidae, or roaches. They are destructive to wood foundations. They penetrate the wood lengthwise with the grain and, under favorable conditions, may reach the second and third story. Their burrowing through the wood reduces it to a powder.

Wooden foundations, floors, posts, wooden door frames imbedded in the concrete floor, etc., offer suitable avenues for the entrance of termites. Termites cannot live without contact with the moisture of the soil. Breaking this contact, by solid masonry, or by providing metal shields that prevent their return to the soil, keeps them away, and those that have already entered die. The painting of the ends of the timber assists in preventing their penetration of the wood.

Termites may also be exterminated by means of soil poisons placed about the foundation. For this purpose Snyder[10] recommends full strength of crude liquid orthodichlorobenzene. The poison is applied in a trench 2 to 3 inches deep, close to the foundation walls, both on outside and inside, and around pillars. The amount recommended is one gallon per 10 linear feet. For such treatment the user may obtain detailed advice and assistance from the State and Federal Departments of Entomology.

Rodents.—Mice and rats not infrequently invade the creamery, damaging supplies and jeopardizing the product. Their extermination in some localities is a real problem.

Mice usually can be eliminated by continuous trapping until they have disappeared. Rats generally shun traps after a few baitings. They can be successfully exterminated, however, by systematic baiting with an efficient poison bait, such as bait poisoned with "Ratmort."

For preparing the bait, very ripe bananas are mashed into a fine pulp and the pulp spread thinly on toast. The toast is cut into small pieces, which are then soaked in "Ratmort." The runways of the rats are then covered with this bait, about three feet apart. The same bait is also used to cover the rest of the building. It is advisable to use a sufficient quantity so as to get all the rats at one time, if possible.

After a two weeks' interval, the same procedure may be repeated, but instead of using bananas and toast, using tuna or salmon, without toast, soaked in the "Ratmort." The advantage of this type of poison lies in the fact that it largely eliminates the presence of dead rats in the plant. It appears that the first effect is for the poison to choke the lungs, driving the poisoned rats outside for air before they die.

The rat menace is usually a characteristic of the neighborhood, such as vicinities of horsebarns, alleys filled with diverse rubbish, and similar breeding places. Danger of invasion of the creamery can obviously be minimized by keeping masonry and walls intact, repairing defective walls and providing close fitting doors, absence of broken panes in windows, and efficient trapping of sewer drains.

REFERENCES

1. Phillips, A. W., Mack, M. J., and Frandsen, J. H., Mass. Agr. Expt. Sta. Tech. Bul. 13, (1928).
2. Barnum, H. J., Lucas, P. S., and Hartsuch, B., Mich. Agr. Expt. Sta. Spec. Bul. 262, (1935).
3. Tuckey, S. L., Ill. D. Mfg. Confer. 33, (1936).
4. Smither, F. W., U. S. Dept. Commerce B. S. Circ. 383, (1930).
5. Ruehe, H. A., Milk Plant Monthly XXVII, *4*, 30, (1938).
6. Mudge, C. S., and Lawler, B. M., Ind. Eng. Chem. *20*, 378, (1928).
7. Levine, M., Peterson, W. E., and Buchanan, R. E., Ind. Eng. Chem. *19*, 1338, (1927).
8. Levine, M., Tolouse, J. F., and Buchanan, R. E., Ind. Eng. Chem. *20*, 179, (1928).
9. Myers, R. P., J. Agr. Res. *38*, 521, (1929).
10. Snyder, T. E., U. S. Dept. Agr., B. E. Leafl. 101, (1933).

PART II

Milk and Cream Supply

CHAPTER VI.

CARE OF MILK AND CREAM ON THE FARM

The cardinal requisites in the production of wholesome and good-flavored milk and cream are: healthy cows and attendants, wholesome feed and pure water, absence of feeds and weeds that produce objectionable flavors and odors, attention to cleanliness of utensils and sanitation of operation, prompt cooling, frequent deliveries, and protection from heat in transportation.

Healthy Cows and Attendants.—Milk from cows suffering from specific bovine diseases, such as tuberculosis, foot and mouth disease, infectious abortion, udder diseases, etc., is unsafe for consumption and manufacture, because of the possible presence of disease organisms in the milk. Milk or cream from such cows may jeopardize the health and life of the consumer. Efficient pasteurization will destroy the living germs, but it will not eliminate the damaging products that may have resulted from their activities.

Likewise, the health and habits of the attendants—the persons doing the milking and caring for the milk and cream and for the milk utensils—are controlling factors in determining the safety of milk and its products to the consumer. The production of safe milk requires that the attendants themselves be in good health and free from germs of infectious or contagious disease. They must have cleanly habits and should not associate with persons suffering from disease.

Aside from the presence or absence in milk of germs of disease, its wholesomeness is affected also by the general physical condition of the cows, because of the influence which this condition may have on the physiological functions of the cow. Milk secretion is a physiological function. If this function is abnormal, the properties of the resulting product—milk—may also be, and often are, abnormal. Any condition which materially disturbs the physiological functions of the cow, therefore,

tends to disturb the normal chemical, physical and physiological properties of milk and its products, and jeopardizes their wholesomeness, flavor and market value.

Proper Feed and Water.—Besides jeopardizing the health of the cows, the feeding of unwholesome, decayed feed, such as moldy hay and straw, moldy silage and grain, fermented distillery slops, spoiled roots and root tops, etc., tend to impart to milk and its products undesirable flavors characteristic of the condition of such feeds.

Certain feeds, such as silage, rye pasture, beets, turnips, cabbage, sweet clover, etc., when fed in excessive quantities, give milk, cream, and butter, flavors which are not desirable. The danger from these feed flavors may be greatly minimized by feeding such feeds four to six hours before milking.

Some weeds, particularly wild onion, garlic, leek, French weed, peppergrass, ragweed, cause milk, cream and butter to be impregnated with most intense off-flavors, which are very difficult to remove. These objectionable flavors are usually more intense in and less readily removed from cream than milk, and their presence in butter greatly depreciates its market value and usually causes heavy financial loss to the creamery. The surest way to prevent these flavors in milk, cream and butter is to completely eradicate these weeds from the pastures by burning, plowing up and rotation of crops as recommended by the U. S. Department of Agriculture Farmers' Bulletin 610. For further details on feed and weed flavors see Chapter XII on "Removal of Objectionable Flavors and Odors from Cream," and Chapter XXIII under "Defects in Flavor and Aroma."

Cleanliness.—Contact of milk and cream with anything that is unclean, be it the cow, the milker, the stable air, or the milk utensils, is a detriment to quality. The damage may result from absorption of objectionable flavors and odors or from contamination with undesirable bacteria. It is, therefore, of the greatest importance to produce milk and cream with due regard to cleanliness of premises and of all utensils, and to sanitary care in its handling, from cow to creamery.

Importance of Systematic Care.—The accomplishment of clean cream of low germ content and good quality depends primarily upon personal standards of cleanliness and systematic

attention to all important details in the production and care of the cream, and in the care of equipment and utensils. Suitable facilities assist in dignifying the work and in making it easier, but they are of little benefit in the absence of an approved systematic routine of care, that is conscientiously followed through in all operations each day.

The barnyard should be kept well drained and free from manure, so that the cows are not compelled to wade knee-deep in mud before they enter the stable. The stable must be kept free from abnormal accumulations of dirt, dust, cobwebs and manure; the manure must be removed at least once daily; the bedding must be clean and the stable sufficiently ventilated to eliminate strong animal and manure odors; the floors should be sprinkled with water before sweeping and the sweeping completed several hours before milking, so as to give the dust in the air a chance to settle before the milk is drawn and exposed to the stable air.

The cows must be kept clean. The surest way to keep their udder and flanks clean and free from filth and manure, is to provide a clean, dry yard and clean bedding in the stable. Udder and flanks should be wiped off with a clean damp cloth before milking commences. The currying of the cows should be done after and not before milking.

The milker must be embued with a sufficient sense of cleanliness and decency to milk with clean, dry hands, and to protect

Fig. 16. Milk strainer

Fig. 17. Can cover with cream strainer

Courtesy of Creamery Package Mfg. Company

the milk from undue contamination with dust, dirt, and other impurities. It is his ideals and his conception of sanitation and cleanliness that largely control the presence or absence of contamination of the milk during its production.

In the handling of milk and cream on the farm the sanitary condition of the milk utensils is an important factor in determining the quality of the cream. Unclean utensils seed the cream with a variety and with large numbers of micro-organisms, most of which when given time, cause fermentation that impairs quality.

The utensils must be clean and as nearly sterile as possible. To accomplish this, all pails, dippers, strainers, coolers, cans, etc., should be rinsed after use, with cold or lukewarm water, washed thoroughly with hot water containing some washing powder, and then scalded with boiling hot water, or steamed if steam is available. If machine milking is practiced the teat cups and rubber tubes should be thoroughly washed and soaked between milkings in a solution of a suitable disinfectant, and the pulsators, pails and accessories must be regularly washed and scalded.

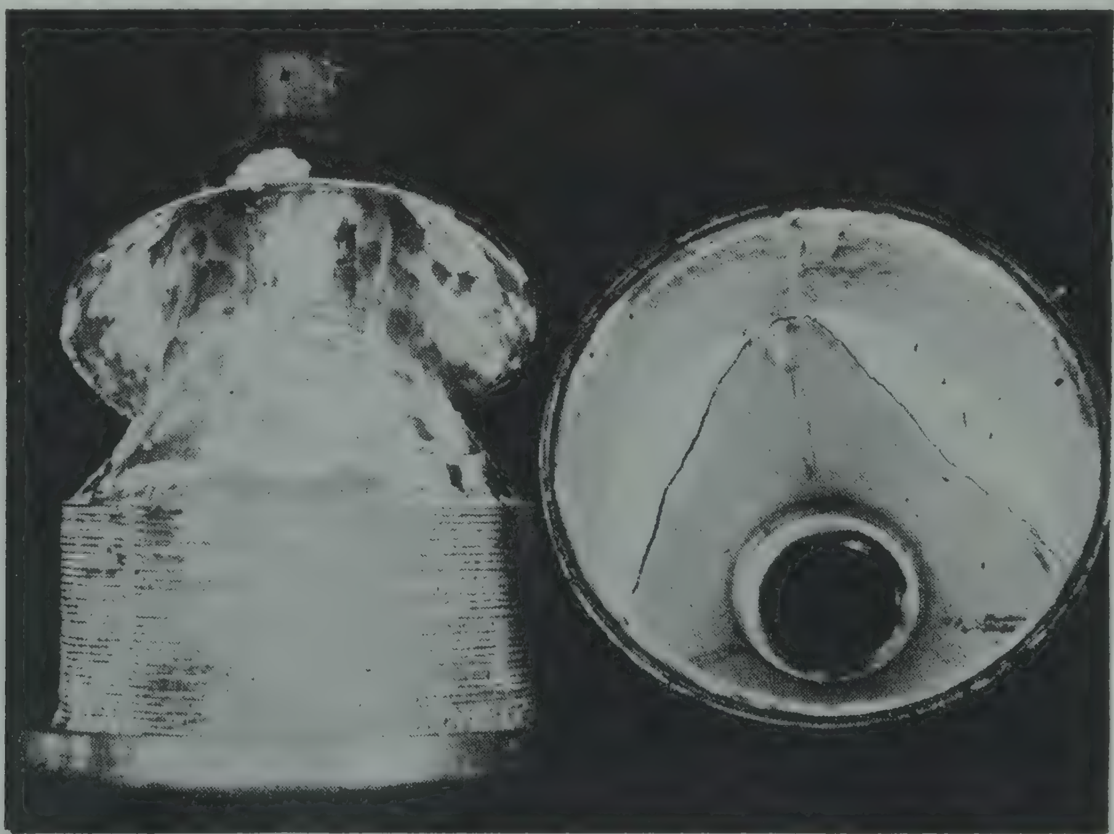


Fig. 18. Unwashed separator bowl.

Sanitary Operation and Care of the Cream Separator.—The milk should be properly strained before it passes through the cream separator. The cream, as it comes from the separator,

should be strained through a strainer that covers the top of the cream can, in order to guard against contamination of the freshly separated cream with dust or flies, etc. The separator bowl and all accessories that come in contact with the milk and cream, need washing after each separation. Impurities and remnants of milk collect between the internal contrivances, and deposit as separator slime on the wall of the bowl. If left in the bowl between separating times, this material starts decomposing and will thus contaminate the cream of the next separation, greatly depreciating its quality. These decomposing remnants in the unwashed separator likewise interfere with its skimming efficiency and corrode the metal parts, shortening the life of the machine.

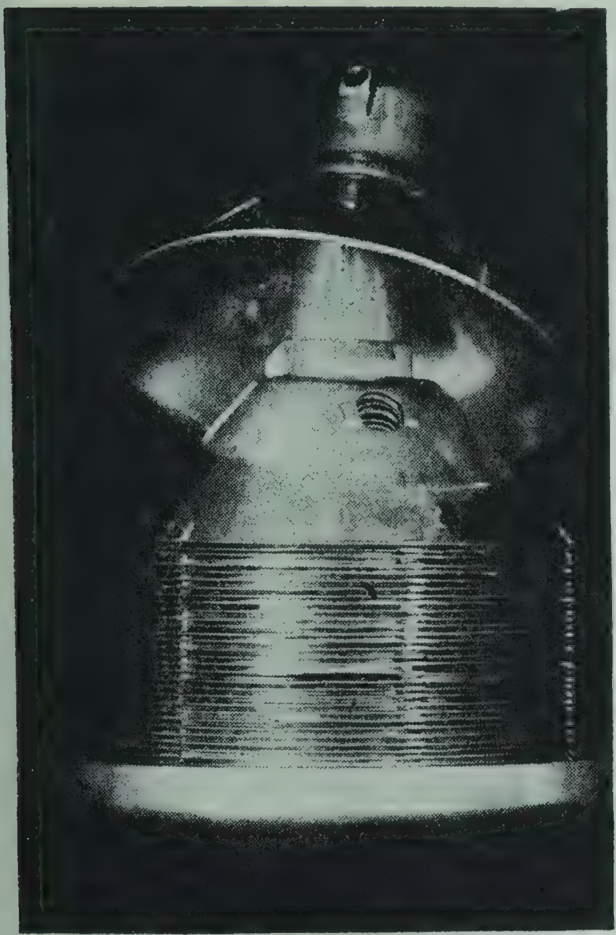


Fig. 19. This bowl was flushed after use. If not taken apart and washed, it will be foul-smelling at the next separation

Care of Cream After Separation. — Next in importance to cleanliness is prompt and proper cooling. The freshly separated cream usually still contains animal heat. Unless this is removed by cooling, it develops in the cream an objectionable smothered flavor that is foreign to the flavor of good butter.

Furthermore, and more important, all cream contains diverse forms of germ life. This is true even of cream produced with due regard to precautions against preventable contamination. If the activity of the micro-organisms contained in the cream is not checked by low temperature, they multiply rapidly and cause early deterioration of quality. The effect of temperature on bacterial multiplication in cream was experimentally demonstrated by Wilster, Hoffmann and Brandt,[1] whose results are shown in Table 8.

Table 8 shows that, when the cream was held at 42° F., there was practically no increase in bacteria during the entire period of 72 hours. As the temperature of holding was raised the number of bacteria increased. The decrease after 48 hours

Table 8.—Rate of Growth of Bacteria in Cream Held at Different Temperatures

Temperature	Number of Bacteria in 1 cc. of Cream				
	When Fresh	After 12 Hours	After 24 Hours	After 48 Hours	After 72 Hours
Set in Refrigerator at 88° and held at 42° F.	8,300	12,000	10,600	11,000	14,200
Held in Flowing Water Temperature 51°-52° F.	8,300	13,300	42,000	1,360,000	10,000,000
Held in Room Temperature 52°-66° F.	8,300	24,000	730,000	55,000,000	550,000,000
Held in Incubator Temp. 72° F.	8,300	19,000,000	179,000,000	182,000,000	425,000,000
Held in Room Temperature 72°-81° F.	8,300	16,300,000	134,000,000	229,000,000	160,000,000
Held in Incubator Temperature 98.6° F.	8,300	214,000,000	218,000,000	2,870,000	2,830,000

in the case of the highest storage temperature is attributable to the usual observation that the lactic acid bacteria reach their peak early at these high temperatures. After that they begin to degenerate and die off on account of the high acidity that becomes unfavorable to their growth and life. When that point is reached, other species gain the ascendency and, while they multiply at a slower rate than the typical lactic acid species, they are far more damaging to quality. This is one of the dominant reasons why uncooled cream deteriorates to a very inferior quality with age.

For best results the cream should be cooled as soon as it comes from the separator. The beneficial effect of cooling then is greatest. Delays in cooling invite the initial stages of fermentation. Once started, fermentation continues and is difficult to check. Prompt cooling keeps the cream sweet and in satisfactory condition longest.

The lower the temperature to which the cream is cooled (above the freezing point), the more effective is the check on bacterial development, and the longer will damaging deteriora-

tion of the cream be deferred. However, even cooling to ordinary room temperature (70° F.) does some good and is preferable to no cooling at all.

Aside from retarding flavor deterioration, prompt and proper cooling with frequent stirring also keeps the cream in better physical condition, making possible its transfer to the shipping can without excessive loss of fat, and facilitating the taking of representative samples from such cream, which in turn is the foundation of accurate tests for fat.

How to Cool the Cream.—As shown in Table 8, the ideal way of cooling the cream is to hold it in a refrigerator at 45° F. or below. This is feasible on farms that possess a mechanical refrigerator. In this case it is customary to transfer the pail or crock of cream from the separator to the refrigerator and hold it in there until shipping time. Or, in case of a refrigerator too small to hold all the cream that accumulates between shipping times, the cream of each separation may be held in the refrigerator for 24 hours and then poured into the shipping can set in cold water. Patrons who have these facilities, follow the above practice, and make reasonably frequent deliveries, are usually supplying a cream of uniformly good quality.

Fig. 20. A practical cream cooling tank.

In the absence of the mechanical refrigerator, cooling in ice water makes possible satisfactorily rapid cooling to a sufficiently low temperature. Setting the cream in a cool place, such

as the basement of the house, or a storm cave, or a dry well, is of some help, but the cooling effect is slow and the temperature cooled to, generally not low enough to prevent deterioration. The basement is an objectionable place for the further reason that its atmosphere usually has a characteristic cellar odor that impregnates the cream.

Cooling in water is preferable to air cooling, because the heat transfer efficiency of water is 21 times as great as that of air. The cream cools 21 times as fast in water as it does in air of the same temperature. Cooling in water is most efficient, if the cream is allowed to flow over a water cooled metal surface (a surface cream cooler) direct from the separator. This, however, calls for extra equipment to install, use and take care of, and it is usually not available on farms that milk only a few cows.

It is within the financial reach of every cream producer, however, to provide a simple cream cooling tank, preferably insulated, in which the cream can is immersed in cool water. If running water is available, that much the better, but even one or two renewals of the water per day, will help to retard flavor-damaging fermentation. If the cream cooling tank is

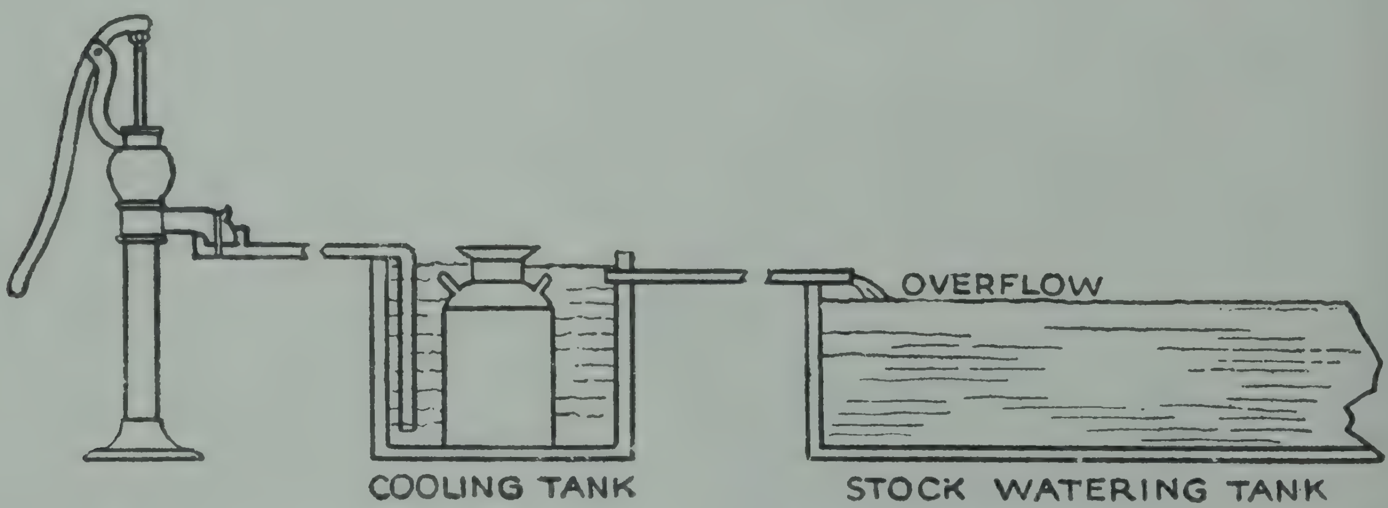


Fig. 21. From well pump to cream cooling tank, to stock-watering trough

installed between the water supply (well pump or running spring) and the stock watering trough, the water that cools the cream also supplies the water needed for the farm stock.

The cream cooling tank need not be elaborate nor costly. A pickle barrel with water intake and overflow serves the purpose. It should accommodate at least two cans, one containing the freshly skimmed warm cream, and the other holding the cooled cream that is accumulating for delivery. The fresh, warm

Table 9.—Effect of Cooling Cream on Farm on Quality of Cream and Butter**

Factors Determined	Preliminary Experiment Before Using Tanks		Experiment With Cooling Tanks		Reduction of Acidity and Bacteria and Increase of Score and Price
	Prospective Tank Users	Prospective No-Tank Users	No-Tank Patrons	Tank Patrons	
Ave. mean atmos. temp.	65.5° F.	65.5° F.	60.9° F.	60.9° F.	....
Cream Acidity	.52%	.52%	.52%	.38%	— 26.9%
Cream Scores	Not re	corded	88.75	91.25	+ 2½ pts.
Bacteria in Cream* Total Count	275,500	295,000	226,750	147,125	— 35.0%
Acidifiers	162,000	178,000	131,125	84,125	— 35.8%
Liquefiers	13,262	17,666	37,931	10,637	— 72.0%
Yeast and Molds	2,162	2,104	2,059	515	— 75.0%
Bacteria in Butter* Total Count	722	733	1,511	600	— 58.6%
Acidifiers	340	332	917	365	— 60.2%
Liquefiers	341	317	297	53	— 81.9%
Yeast and Molds	75	92	78	10	— 87.4%
Butter Scores and Price Purdue	89.3	89.5	88.98	91.63	Increase in score + 2.65 pts.
New York	87.5	87.1	87.69	89.70	+ 2.01 pts.
Average Score	88.4	88.3	88.36	90.69	+ 2.33 pts.
Price received for sale	23½c	23½c	23.94c	24.88c	+ .94c

*The figures represent number of 1000 germs per gram.

**Two cream routes of the Purdue University creamery of 20 patrons each, were used for the above experiment. One-half of the patrons of each route were supplied with cream cooling tanks, while the other half operated without these tanks. The cream was hauled to the creamery twice per week, the tank-cooled cream and the no-tank cream were kept and churned separately. The same methods of handling and of manufacture were used with all lots of cream. In order to make sure that, aside from the use of cream cooling tanks, the cream of both groups of patrons was produced and handled under as near as possible the same standard of sanitation and care, a preliminary experiment was made before cream cooling tanks were installed, the results of which are recorded in the first two columns of Table 9. They show that the quality of cream and butter from both groups of patrons was practically the same. It must follow, therefore, that any difference in results of the experiment proper, of the cream produced and butter made between the tank-cooled cream group and the no-tank cream group, may be consistently attributed to the use of the cream cooling tanks.

cream should never be poured in the cooled cream of earlier separations. It should be first cooled before mixing, as a mixture of new warm cream with stored cooled cream will spoil rapidly.

The ideal cream cooling tank is large enough to hold a sufficient body of water to avoid rapid warming up. It is sufficiently insulated to hold the temperature within a few degrees for eight to twelve hours. It is deep enough to allow the water to cover the cans at least as far up as the cream will reach when the cans are full.

Aside from its fundamental purpose of cooling the cream, the cream cooling tank furnishes a desirable place for storing the cream from the sanitary standpoint. It protects the cream against contaminating odors, dust, dirt, flies, ants, gnats, and other insects, and rodents. The cream should be covered to insure protection against these contaminating agencies.

A practical and convincing demonstration of the beneficial effect of the use of the cream-cooling tank, on the score and market value of butter is provided by the work of Hunziker, Mills and Switzer[2] as summarized in Table 9. For description of the experiment see table footnote appended to Table 9.

Table 9 gives the averages of all churnings made from tank-cooled cream and from no-tank cream. The average acidity for the tank-cooled cream was .38% and for the no-tank cream .52%. The total bacteria count of the tank-cooled cream was 147,125,-000, as against 226,750,000 for the no-tank cream. The maximum difference in score of butter between individual churnings was 5.5 points in favor of tank-cooled cream, the average difference in favor of the tank-cooled cream was 2.33 points. The maximum difference in price received for the butter, sold on the open market, was 3 cents in favor of the tank-cooled cream. For all churnings the butter from the tank-cooled cream averaged .94 cents higher returns than that from the no-tank cream. In the fermentation test the tank-cooled cream yielded a normal smooth coagulum, while the curd of the no-tank cream was torn and gassy. The sediment discs of the tank-cooled cream were relatively clean, while those of the no-tank cream showed considerable accumulations of dark colored extraneous matter.

The above experimental results of work done under commercial conditions, furnish indisputable evidence of the advantages and the economic value of the use of cream-cooling tanks on the farm. They show that the cream is lower in acid and

in bacteria, yeasts, and molds, and that the butter made from such cream has a lower bacterial count, scores higher, and brings a higher price on the open market.

Age of the Cream.—The shorter the time between milking and churning, the less the danger of fermentations that are damaging to the quality and market value of the butter. No treatment in manufacture has as yet been evolved, that will return old, stale, fermented cream to its original state of freshness. Such cream will not make butter of high quality.

Cream is a highly perishable product. Like other, similar food products, it is best when fresh. It should, therefore, be marketed, or used for manufacture, as early as possible after it leaves the separator. Age will gradually deteriorate cream under any condition. While proper care in its production, handling and storage retards age deterioration, it will not prevent it. If intended for the sweet cream trade, the cream should be delivered daily. If sent to the creamery for butter manufacture, deliveries should be made at least three times per week in summer, and twice per week in winter, or preferably oftener.

Old age of cream is the arch-enemy of the butter industry. It intensifies the damaging effect of all other deteriorating agencies to which it may have been subjected. It prolongs the time during which such contaminating influences as bacteria, yeasts, molds, enzymes, metallic salts and air can do their quality-destroying work, it magnifies the decomposition-promoting effect of high temperature. Efforts at cream improvement that ignore the indispensable factor of frequency of delivery, are doomed to inevitable failure.

Metallic Status of Container and its Relation to Cream Deterioration.—The cream containers used on the farm and for shipping are predominatingly constructed of tinned iron. Tin is practically inert from the standpoint of its effect on the cream. It does not damage the cream. Iron, on the other hand, is readily attacked and corroded by the acids and minerals contained in the cream, and the iron salts resulting from this corrosion are highly detrimental to its quality.

As long as the tin coating in the cans remains intact, the possible damage to the cream is negligible. The tin coating, however, is vulnerable to high acid cream and to most of the alkalies used in can washing. Its life, therefore, is of relatively

short duration and the cans soon expose spots of bare iron, which rust profusely. Such cans are a menace to the quality of the cream. The cream that comes in contact with the sides and bottom of such cans, almost invariably shows a disagreeable, puckery, metallic taste that is carried into the butter.

Efforts at quality cream should embrace close attention to the cream containers used on the farm and for shipping. Rusty cans should be retinned or, if beyond repair, replaced by new ones. For further details on effect of metals see Chapter IV under "Metals in Creamery Equipment."

Air, as a Factor in the Deterioration of Cream.—Prolonged exposure of the cream in the can to air, favors the growth of molds, yeasts and bacteria, contributing to and hastening age deterioration. It has, therefore, been thought that the elimination or curtailment of this air would be helpful in efforts to preserve the freshness of the cream. This in turn has led to the development of special containers and the advocation of diverse methods intended to exclude the air from the cream can, such as the air-tight can sponsored by Parfitt and Galema;[3] the use of a cupped disc on the surface of the cream recommended by Bouska, Brown, Irwin and Tuttle;[4] the replacement of the air by an inert gas suggested by the same investigators; the vacuumizing of the can promulgated by Reed.[5]

Parfitt and Galema used a cylindrical cream can, the Chalfant can, that is equipped with a so-called air-tight cover fastened to the can with spring clamps. Aside from its air-tight feature, the spring clamps serve as an automatic pressure release. When gas pressure forms in the can the cover raises sufficiently to release the pressure and the spring clamps automatically pull the can lid back to form a tight seal, preventing the air from entering.

Bouska et al. conceived the idea of excluding the air from the surface of the cream by laying on the top of the cream a cupped metal disc, similar to an ice cream can cover. These same investigators also suggested the replacement of the air in the can with an inert gas by introducing a small piece of dry ice after each skimming. The dry ice melts rapidly and fills the space above the cream with CO_2 which, because of its being heavier than atmospheric air, remains in the can, displacing the air.

Reed provided a bead in the neck of the standard cream shipping can, on which rests a metal disc that seals the can. The disc is equipped with a self shutting rubber valve. With a vacuum pump (a bicycle pump acting in reverse), he draws a vacuum (about 23 to 25 inches) on the can through the self-sealing rubber valve, thus holding the cream in a partial vacuum.

Each of these methods has its theoretical merit. They all have been tried out with varying success. None have solved the problem of practical application on the farm. If their use were practically feasible, they might be reasonably expected to be of some limited benefit. Contrary to some of their advertising claims, however, they would not eliminate or diminish the necessity of attention to the fundamentals of proper care, as discussed in preceding paragraphs. There is no substitute for cleanliness, low temperature and frequency of delivery. There are no short cuts in the production of cream of good quality.

Protection of Cream in Transit.—The conditions to which cream is exposed in transit, from farm to cream station and from cream station to creamery, by rail and by truck, are an important link in the chain of factors that determine its quality upon arrival at the butter factory. The same trio of fundamentals — cleanliness, low temperature, and freshness — that underlie the production of good cream on the farm, apply to the handling of the cream in transit.

Protection Against Contamination in Transit.—The shipping can, or other container in which cream is transported, must be clean. It must be in good repair and, if of metal, it must be free from rust. Unwashed returned empties should be thoroughly cleaned upon arrival at the farm, preferably with brush and hot water containing mineral washing powder, followed by a good rinse with boiling hot water. They should then be allowed to dry, by inverting them for draining and aeration in a clean place where they are protected from dust. Washed cans returned from the creamery or cream station should be opened and placed where they can dry and aerate. All cans should be rinsed with clean water immediately before use to insure freedom from dust and other extraneous matter.

In order to protect the cream against the possibility of defilement in transit the cans should be securely sealed, such as by fastening down the can lid with suitable wires or other

proper can seal that will guard against removal of the can cover in transit. The carriers–trucksters, route haulers and railway agents–should see to it that the cream cans are kept away from undesirable or insanitary baggage or freight, such as vegetables, fruit, fertilizer, crates of chickens on top of the cans, or calves or other live stock tied to the cans. Any defilement of the outside of the can and can cover is objectionable. When the cans are subsequently emptied and steamed over the weigh can or fore-warmer, such extraneous matter may easily drop into the cream. Farm produce and other freight of the above nature, if it must be carried on the same truck or car, should be partitioned off, away from the cream cans.

Protection Against Heat and Cold in Transit.—The cream should be kept in cooling water on the farm until shipping time. At the cream station there is also need of facilities to keep the cream cool in hot weather, while awaiting transfer to the creamery. This may be done by the use of a cream cooling tank, by placing the cans under a spray of cold water, or by setting them in individual pig feed trays filled with water and slipping a well soaked burlap sack over each can, the open end of the sack dipping into the water in the feed tray. In this case the sack is automatically kept moist by capillary attraction as long as there is water in the tray, and the evaporation of moisture from the sack keeps the can cool.

On the truck the cream cans should be covered with a wet tarpaulin in summer and a dry one in winter. At the railway station the co-operation of the station agent in placing the cans, as they arrive on the platform, in the shade, and keeping them away from heated stoves and steam pipes in the baggage car, will materially help in delaying damaging fermentation and deterioration. At some railway stations a cooling tank is provided for the cream cans. On truck routes a shelter may be provided on the route platform by the farmer, that will keep the cans shaded from the sun.

Rapidity of Movement of Cream in Transit.—The patron himself is in a position to shorten the time during which his cream is enroute, by timing his delivery to the railway station, or route platform, to synchronize with the scheduled arrival of the train or truck. Prompt shipping after arrival at the shipping point is important. The Station Agent may expe-

dite transit by advising the farmer of the exact train time. It is in his power to route the cream cans on trains that will make the most direct connections, to ship the cream on the first train after delivery at the station, and to enlist the co-operation of the agent at the transfer point for promptly transferring and loading on the next train.

In the case of route cream, the hauler should deliver the cream to the creamery promptly upon arrival in town. The cream station operator also should avoid unnecessary delays in sending his cream to the creamery.

Prompt Return of Empties.—Another most important phase in transportation, which affects quality of cream, is the prompt return of the empty can. The farmer depends on the return of the empty can for his next shipment of cream. Usually he has no other can in which to make his next shipment. If he does not receive the can promptly, he must hold his cream longer than he should, and in receptacles that are often not suitable for the purpose. All of this means danger of contamination, older cream, greater deterioration, and poorer quality.

In the case of door deliveries, route cream and station cream, the empties are usually returned on the same conveyance that brought in the full cans, and delays are avoided. In the case of direct shipper cream arriving by rail, there are numerous possibilities of delays in the return of the empty cans, such as neglect on the part of the creamery to bring the washed empties to the railway station in advance of train time, or causing the address on the tag to be incomplete or incorrect; neglect on the part of the station agent at the point of departure to put the cans on the train promptly, causing them to accumulate; or carelessness that results in loading cans on the wrong train; or unloading them at the wrong station.

The creamery personnel and the carrier should realize that the empty can is as perishable an article as the full can, because delay of its return may spoil the next shipment of cream, and that, therefore, all empties should be returned as promptly as possible. They should be placed on the earliest train, on the right train, and unloaded at the correct destination. Proper attention is needed also at transfer and concentration points. Cans should not be allowed to lie around and accumulate on railway station platforms. If they are not called for by the shipper, the shipping tag should be inspected. If the address

on the shipping tag does not correspond with the respective station, the can should be rerouted to its proper destination without delay.

Efficient Transportation Means Business for Cream Carrier.—It is to the interest of the railway carrier to render such service to the dairy industry, as to reduce deterioration of the cream in transit to the minimum. Butter of good quality, such as can be made from good cream only, increases consumption and this in turn stimulates production. It means more farmers engaging in the production of cream and more cows to the farm. This, in turn, means more cans of cream to ship from farm to creamery, more butter to ship from creamery to market, more supplies, coal and equipment to ship to the creamery, and more raw material to ship to factories manufacturing supplies and equipment for farm and creamery.

Prompt Removal of Cream Cans from Railway Terminal to Creamery.—Finally, the last link in the chain of cream transportation is that between railway terminal and creamery. Here again delays augment the danger of cream deterioration. This phase is under the immediate control of the creamery. The creamery operator is in a position to reduce deterioration at this point to the very minimum, by so organizing his contact with the railway station, as to insure prompt removal of the cream from station to creamery. This is especially important during the season when both the days and the nights are hot.

Care of Milk and Cream in Factory.—The treatment given the milk and cream upon arrival at the factory and before manufacture, may and often does have a marked influence on the quality of the finished butter. Prolonged holding before manufacture is undesirable, as it invites fermentation due to bacterial action. The danger here is especially great during warm weather. However, even under conditions that permit of temperature control, prolonged holding does not improve, and may injure quality. It is important, therefore, to organize the factory routine so as to make possible prompt use of the raw material upon its arrival.

Milk, wherever possible, should be heated promptly preparatory to separating. If conditions are such as to necessitate holding for a considerable time, it should be cooled to 45°F

or below, or if already cool, it should be held in the cold room until needed.

Cream should be graded, sampled, weighed, and "dumped" as fast as it arrives at the factory. Cream received too late in the day to permit of manufacture on the same day, may be held over night on the cream room floor during the cold season. During warm weather, however, such procedure invites intense fermentation and may cause the cans to foam over. Setting the cans in the cooler usually fails to check bacterial action sufficiently rapidly to prevent fermentation. This is due to the fact that the cream in the cans is often warm when it arrives and mere exposure to a cool atmosphere does not lower the temperature of the cream rapidly enough. Running such cream over a cooler, or setting the cans in cold water would be the most effective way to retard fermentation. In the absence of these facilities the danger of damage to the cream may be materially reduced by the use of a cold water spray, similar to a lawn sprinkler. The cans are placed under one or more sprinklers in a position that causes the water spray to trickle over all the cans. In the case of holidays and Sundays, it is preferable to "dump" the cream, pasturize and cool it. When this is not feasible the use of the cold water spray, or setting the cans in the cold room, will help to minimize the danger of fermentation.

REFERENCES

1. WILSTER, G. H., HOFFMANN, H., and BRANDT, P. M., Ore. Agr. Expt. Sta. Bul. 326, (1934).
2. HUNZIKER, O. F., MILLS, H. C., and SWITZER, H. B., Purdue Agr. Expt. Sta. Bul. 188, (1916).
3. PARFITT, E. H., and GALEMA, M. L., Nat. Butter and Cheese Jour., p. 13, (1931).
4. BOUSKA, F. W., BROWN, J. C., IRWIN, W. H., and TUTTLE, C. O., Am. Cry. and Poultry Rev., p. 671, (1930).
5. REED, D. L., Gold Coin Cry. Co., Denver, Colo., (1936).

CHAPTER VII.

THE SEPARATION OF MILK

Purpose.—The purpose of separating milk is to obtain cream. Cream is that portion of milk into which has been gathered, and which contains a large portion of the milk fat. The principal objects of using cream for buttermaking, instead of churning milk, are:

1. To reduce the volume of fluid to be churned, thereby increasing the operating capacity per pound of butter made, of all equipment used in the process of manufacture, and economizing fuel, power, refrigeration, time and labor in the operation and care of the equipment and in the handling of the product.
2. To accelerate the speed of the churning process.
3. To decrease the volume of buttermilk produced, thereby reducing the percentage of fat lost of the total fat churned.

Aside from butter manufacture, large volumes of milk are separated for purposes other than churning, such as to provide cream for table use, ice cream making, whipped cream, etc., and for standardization of milk and milk products.

Principle of Separation.—The separation of cream from milk is based on the principle that butter fat is lighter than the other constituents of milk. At 60°F. the specific gravity of average milk is about 1.032, that of butter fat about .93 and that of skim milk about 1.037. The fat globules, containing the butter fat, therefore, yield to the force of gravity and rise to the surface.

In the separation of cream considerable portions of water and of non-fatty milk solids are carried into the cream. Generally speaking, the relation of solids not fat to water in the cream is approximately the same as it is in milk. The per cent of solids not fat in cream, however, is lower than the per cent of solids not fat in milk. It varies inversely with the per cent of fat.

In the absence of facilities for the accurate determination of the total solids and solids not fat, the per cent solids not fat in cream may be estimated by deducting the per cent fat from 100 and multiplying the difference by .09.

Example: Cream tests 35.5% fat. What is the per cent solids not fat?

$(100-35.5) \times .09 = 5.8\%$ solids not fat.

On the basis of the above formula, cream of different richnesses contains the following percentages of solids not fat and of total solids:

Table 10.—Percentages of Total Solids and of Solids Not Fat in Cream of Different Richnesses*

Fat	Solids Not Fat	Total Solids	Fat	Solids Not Fat	Total Solids
%	%	%	%	%	%
18	7.38	25.38	40	5.40	45.40
20	7.20	27.20	45	4.95	49.95
25	6.75	31.75	50	4.50	54.50
30	6.30	36.30	55	4.05	59.05
35	5.80	40.80	60	3.60	63.60

*For further details on composition of Cream, see "Composition of Cream," Chapter XXI.

Methods of Separation.—The separation of milk, as practiced on the farm and in the factory, is accomplished either by gravity or by centrifugal force. In the application of these two fundamental systems of separation the following methods are used:

Gravity separation:
- shallow pan method
- deep-setting method
- water-dilution (or hydraulic) method

Centrifugal separation:
- hand cream separator
- power cream separator

Separation by Gravity

The milk is set at rest in a cool place until most of the fat has risen to the surface, forming a layer of cream. The fat globules rise to the surface because of the fact that they are lighter than the other liquid and solid constituents of the milk.

The Shallow Pan Method.—The milk, preferably fresh from the cow, is poured into a shallow pan about 15 to 25 inches in diameter and about 4 inches deep. The pan is placed in a cool place, such as the cellar, or it may be set in water. After 36 hours practically all of the fat capable of rising by this method

will have come to the surface and the layer of cream thus formed is skimmed off with a spoon, ladle or specially constructed skimmer. The skim milk usually contains about .5% to .6% fat.

The Deep-Setting Method.—The milk, preferably fresh from the cow, is poured into a can of the "shot-gun" type, about 8 to 10 inches in diameter and 18 to 25 inches deep. This can is placed in cold water and held at as low a temperature as possible. Temperatures between 45°F. and the freezing point of water are preferable. At the end of 24 hours the separation is usually as complete as it is possible to secure by this method. The removal of the cream thus separated is most conveniently accomplished by drawing the skim milk from a faucet at the bottom of the can, leaving about one inch of skim milk in the can. In the case of cans without faucets the cream is removed with dipper from the top. The skim milk, under proper conditions of creaming, averages about .2% to .3% fat.

The Water-Dilution Method.—The milk is diluted with equal parts of clean water, usually at about 100°F. and set in a cool place for 12 hours, when it is ready to be skimmed. The skim milk is drawn from the bottom of the can. The greater rapidity of the separation by this method is due to the lesser viscosity of the diluted milk, which permits the fat globules to rise more readily to the surface. The skim milk generally contains from .3% to .4% fat, but since it is diluted to twice its volume with water, the actual loss of fat is equivalent to approximately .6% to .8% in the undiluted skim milk.

CENTRIFUGAL SEPARATION

Definition.—In centrifugal separation, the centrifugal force generated by the rapidly revolving separator bowl is depended upon for the separation of the cream from the milk. Centrifugal force is defined as the force exerted by the reaction of a moving body against a force that causes it to move in a curved path. In the sense of the effect which the centrifugal force has in cream separation, centrifugal force may be considered as the force that causes a body revolving around a central point, to fly outward from the center, as opposed to centripetal force, which is the force drawing a body toward the center around which it revolves. The discus throw of the athlete provides a concrete example of

the cause and effect of centrifugal force. Centrifugal force acts on liquids as well as on solid bodies. For details relating to the invention and development of the centrifugal separator see Chapter I.

The Theory of Centrifugal Separation.—The separation of cream from milk in the centrifugal separator is based on the well known physical law that when liquids of different specific gravities revolve around the same center, at the same distance, and with the same speed, a greater force is exerted on the heavier liquid than on the lighter. Milk, as already stated, consists of two liquids of different specific gravities, the fat particles and the milk serum. The milk enters the rapidly revolving bowl either at the top, middle or at the bottom of the bowl. In most separators it runs first through a central tube which carries it to the middle or bottom before it is discharged into the bowl. In the case of a bowl not in motion the milk fills the bowl from the bottom up due to the force of gravity. When the bowl is rapidly revolving the force of gravity is overcome by the centrifugal force which is from 3,000 to 6,000 times the force of gravity. The milk is therefore thrown immediately to the periphery or side of the bowl, filling the bowl from the side to the center.

While both, the fat portion and the serum portion, are subjected to the centrifugal force, the difference in specific gravity affects the heavier portion, which is the skim milk, more intensely, forcing it to the periphery of the bowl and causing the lighter portion, the fat portion, to recede toward the center. The skim milk thus forms a vertical wall crowding against the periphery of the separator bowl, while the fat globules which are uniformly distributed in the milk before it is subjected to the centrifugal force, are held near the bowl center where they accumulate in the form of a vertical wall of cream, in a similar manner as they gather into a horizontal layer of cream on the surface of the milk in gravity creaming. It is obvious, therefore, that the fat content of the liquid in the revolving bowl is greatest near the center and least at the periphery of the bowl.

As more milk flows into the bowl, the vertical walls of skim milk and cream grow in thickness, filling up the larger portion of the bowl. Under normal conditions of operation, the milk never fills up the entire bowl, a vacant space being left in

the center, except in the case of the Air-Tight Separator, the bowl of which fills completely with milk under pressure. The vertical wall of milk increases until the discharge from the skim milk outlet and that from the cream outlet are equal to the rate of inflow of milk to the bowl.

Relation of Centrifugal Force to Efficiency of Separation.—The intensity of the centrifugal force is controlled by three fundamental factors; namely, the speed and diameter of the bowl and the weight of the contents. It increases in proportion as the weight of the contents and the diameter of the bowl increase, and also with the square of the number of revolutions per minute.

The effect of centrifugal force on the efficiency of separation is in turn determined by the factors of time and manner of separation. The longer the milk is exposed to the centrifugal force, the greater the skimming efficiency. Likewise, the greater the freedom from eddying and short-circuiting of milk in any and all parts of the bowl, the more complete the separation. These factors are controlled by the size of the bowl and the arrangement of its internal contrivances. According to Beckman[1] it is this feature of bowl construction on which cream separator experts have particularly concentrated their efforts within recent years and the results of which have more than quadrupled the skimming efficiency since the appearance of the first centrifugal cream separator. The skimming efficiency is further influenced by the manner of operation. This is discussed in later paragraphs in this chapter.

Construction of the Separator.—The centrifugal cream separator consists of three main parts; namely, the separator frame; the bowl with internal devices, milk supply connections and discharge covers; and the driving mechanism.

The Separator Frame.—The frame of the separator furnishes the foundation and support of all important parts of the machine. It also serves to guide and protect the bowl and its spindle. The base of the frame usually carries the bottom bearing of the spindle which drives the bowl. This bearing is generally equipped with an adjustable screw whereby the bowl may be lowered or raised in its position in the frame. In the case of hand separators the frame is also equipped with supports for the milk supply tank, and for the skim milk and cream cans.

The Separator Bowl and Spindle.—The bowl is the heart of the separator; in it the separation of the milk takes place. In most separators now in use the bowl extends at its lower extremity over the spindle through which is transmitted, either directly or indirectly, the motive power which revolves the bowl.

The bearing on which the spindle revolves may consist of a stationary but adjustable steel point on which a similar steel point at the termination of the spindle rests; or the spindle may terminate in a tapering disc which rests on a bearing of steel balls or steel rollers. The spindle is guided by an upper and a lower ball bearing. The ease of running and elasticity of the bowl may be enhanced by the use of bushings equipped with springs, or with adjustable composition rings.

The bowl proper consists in the main of a cylindrical or cone-shaped vessel. It opens either at the top or at the bottom. It is closed by a cone-shaped cover. At the point of contact with the cover the bowl carries a groove or rim which admits a rubber ring. This serves to make an absolutely tight seal between bowl and cover, without which the pressure generated in the revolving bowl would cause the milk to leak out. Most bowls also carry a central tube through which the milk enters, flows to near the bottom and then is released for distribution and separation. The bowl of the Air-Tight separator is fed from the bottom, as described in later paragraphs.

INTERNAL ARRANGEMENT OF BOWL AND ITS EFFECTS ON SKIMMING EFFICIENCY

Extensive and continued study on the part of the inventors of the continuous flow centrifugal separator has demonstrated that the efficiency of separation suffers when the milk is allowed to enter the separating space of the bowl by continuously passing through the innermost layer of milk, which represents the cream layer. This causes a constant mixing of the incoming whole milk with the separated cream. It was further found that, for maximum skimming efficiency, it is important that the milk be made to circulate with the bowl immediately upon its entrance, that the milk be exposed to the centrifugal force over as long a distance of travel as possible, and that the passage of the fat globules to the cream layer be as unobstructed, as rapid and as complete as possible.

These findings brought about a succession of improvements in the internal construction of the bowl, from the original hollow bowl type to the wing type, the slotted distributor type, and the air-tight type separator bowl. These progressive improvements resulted in a perfection of skimming efficiency and improvement in quality of the cream that is phenomenal, as may be seen from the following description of bowl types and their merits:

The Hollow Type Bowl.—This is the original type of bowl of the Alpha continuous discharge separator, designed by Gustav Patrik De Laval in 1878. The early American-made separator, Danish Weston, also embraced this principle. This bowl had no internal discs. The milk entered through a central tube, and was released near the bottom of the bowl for distribution and separation. In order to enable the milk to partake of the circular motion of the bowl promptly upon its entrance, these bowls were equipped at their periphery with one or more stationary wings extending radially to near the cream layer zone. In this bowl the entering whole milk passed through the zone of separated cream, the cream being carried from the bowl by means of a stationary tube or paring device which extended inside at the top of the bowl.

The Wing Type Bowl.—The wing type bowl introduced the first major bowl improvement with internal devices. In this bowl the milk enters through a hollow shaft with slotted wings and the bowl contains a series of internal devices that not only assist in subjecting the milk promptly to the circular motion of the revolving bowl, but further increase the skimming efficiency by exposing the milk over a longer distance to the centrifugal force and by facilitating the migration of the fat globules to the cream zone. This arrangement still compelled the incoming whole milk to pass through at least a portion of the cream wall, limiting the skimming efficiency to that extent.

Of these internal contrivances the cone-shaped discs of the Alpha separator are the oldest and best known. These tin discs are slipped over the slotted wings of the center tube of the bowl and rest one on top of the other. They leave an open space around the central tube for the gathering of the cream. The upper surface of each disc is spotted with small projections—spacer caulks—for the purpose of keeping the discs at a slight

distance from each other. The intervening spaces divide the milk in its passage from center to periphery into thin layers, facilitating the separating action.

In these machines the skim milk discharges from the periphery of the bowl through small tubes in the bowl cover, carrying it to the common skim milk outlet near the center. The cream is discharged through an eccentric orifice in the cream screw, located in the top of the neck of the bowl cover.

The Slotted Distributor Type Bowl.—This type bowl marked a further important improvement in bowl construction. The milk enters through a central hollow shaft with solid wings to hold the discs in place. It flows to the bottom of the bowl, from where it rises through a series of passageways provided

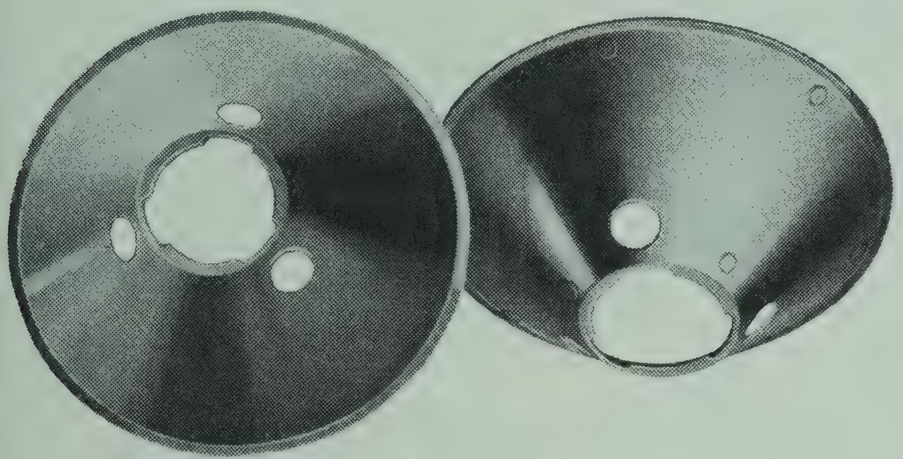


Fig. 22. Passageways in separator discs for the milk, located just outside of the cream zone.
Courtesy of De Laval Separator Co.

by matched perforations in the discs, and reaches the periphery in thin sheets by passing through the spaces between the discs separated by small space caulks.

The significant improvement in this type of bowl arrangement lies in the fact that the passageways (perforations in the

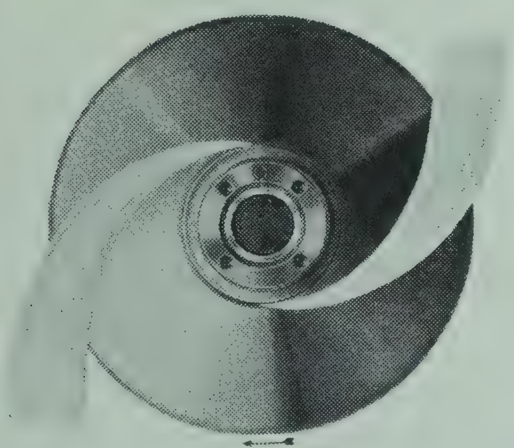


Fig. 23. Trailing skim milk discharge
Courtesy of De Laval Separator Co.

discs), through which the milk rises for distribution to the bowl periphery, are located just outside of the cream zone. By this arrangement the entering whole milk does not pass through

the cream wall, it does not mingle with nor disturb the separated cream and, therefore, materially augments the efficiency of separation over that of the prior types of bowl.

A further improvement lies in the fact that this bowl does away with the small skim milk tubes, the skim milk leaving the periphery in a continuous sheet through the space between top disc and bowl cover, and it is ejected from the bowl through a trailing discharge which expedites its exit and does so with minimum back-pressure and without retarding the speed of the bowl. It also diminishes the foaming or frothing tendency of the skim milk.

The Air-Tight Type Bowl.—The air-tight separator constitutes the zenith of present-day perfection of the centrifugal cream separator. This separator is a hermetically sealed machine in which the whole milk, skim milk and cream are under controlled pressure at all times. This is accomplished by feeding the separator bowl at its bottom through a hollow spindle by means of a positive displacement type of supply pump. This pump is speeded to give the exact capacity required by the separator.

In this type of construction the milk enters the bowl at a high velocity that synchronizes with the speed of the revolving bowl, thereby avoiding the usual shock when subjected to the fast-moving bowl, which tends to mutilate the fat globules. The bowl being air-tight, the product is protected against air pockets, contact with air, and incorporation of air, which hinder separation and cause foaming.

From the hollow spindle that drives the bowl, the milk enters at the bottom of the bowl and passes into a hollow distributor nut, from the ports of which it is forced upward through openings (perforations) in the discs. These openings are located a short distance beyond the center of gravity. At this point separation begins to take place, thus permitting the cream to find its way into the quiescent zone without disturbance from the incoming whole milk. From here the cream passes from the revolving bowl into the stationary density control chamber, which provides external control on the machine by means of a screw valve with graduations, whereby adjustment may be readily made to any desired richness.

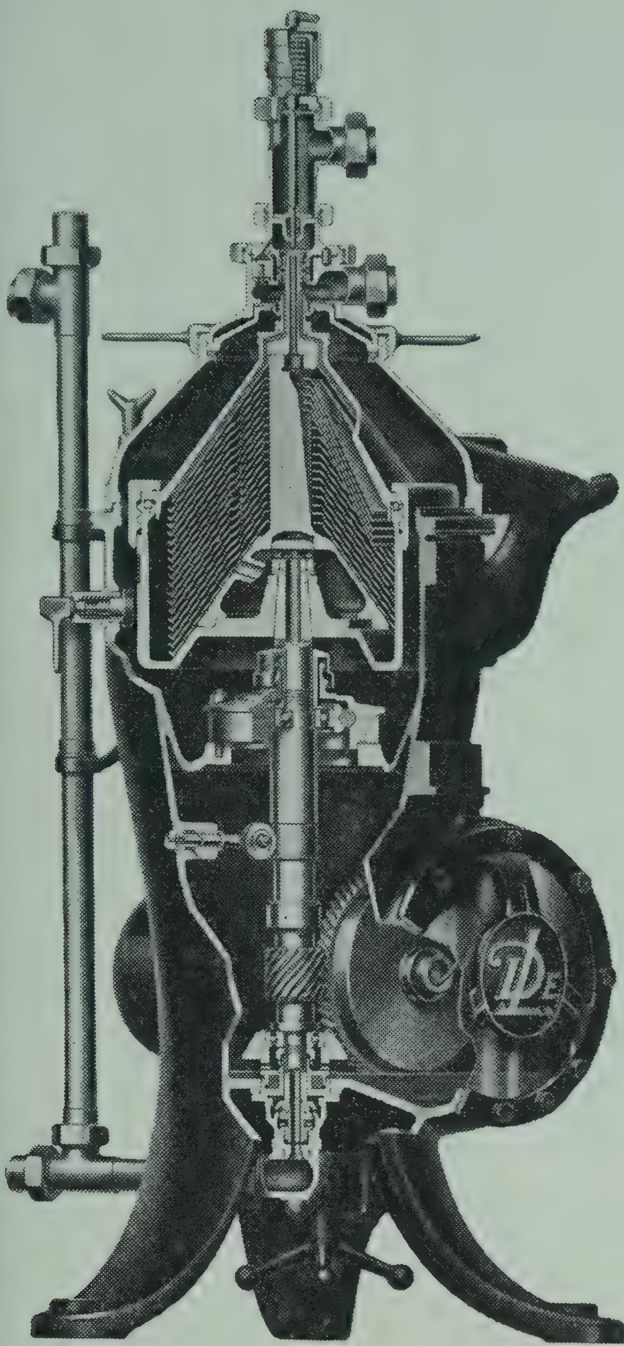


Fig. 24. Air-tight cream separator
Courtesy of De Laval Separator Co.

This type of remote control acts similar to the cream screw type of control in that it simply serves as a choke-back or damming effect for a richer cream, or as a release effect for a thinner cream. It differs from prior types, however, in that it permits of adjustment of the fat content of the cream to any desired richness at any time during operation, i.e., without stopping the separator. This type of control, therefore, lends itself also to the operation of the separator as a standardizer. Being under pressure similar to the cream, the skim milk is forced to the periphery of the bowl and then upward to the final point of discharge into the sanitary line to the outside.

When in operation, the bowl of the air-tight separator is completely full. There is no air space or void in the bowl. The cream accumulates in the exact center of the bowl, where it is at rest and free from the effect of centrifugal agitation. The milk entering the bowl under pressure, and the entire system being air-tight, all air other than that normally contained in the original whole milk, is kept out of the product, there is no foaming of cream or of skim milk, and both, cream and skim milk are delivered at any reasonable elevation without pumping after separation.

The air-tight separator has shown itself an exceptionally close skimmer, yielding skim milk tests well under 0.10% fat by the Mojonnier method, and 0.01% fat or even lower by the Babcock method, as indicated in table 11.

Moreover, it is capable of as clean skimming of milk at a temperature and held under conditions that preclude a melted

Table 11.—Fat Tests of Skim Milk from No. 192 "Air-Tight" Separator at Various Temperatures of Milk.*

Sample No.	Milk Test %	Milk Temperature ° F.	Cream Test %	Skim Milk Test %
1	3.3	78	43.0	0.01 >
2	3.3	80	42.5	0.01 >
3	3.4	85	42.0	0.01
4	3.3	90	42.0	0.01 >
5	3.3	95	42.0	0.01 >
6	3.5	100	42.5	0.01
7	3.4	110	41.0	0.01 >
8	3.3	159	39.0	0.01 >

*Tests made in factory of Abbotts Dairies, Inc., Cameron, Wisconsin, 1936.

condition of the fat globules. This improved skimming efficiency appears to be due to the combined effect of numerous factors that accelerate fat separation. The discs are of thinner metal and the space caulks are thinner, thus making room for more

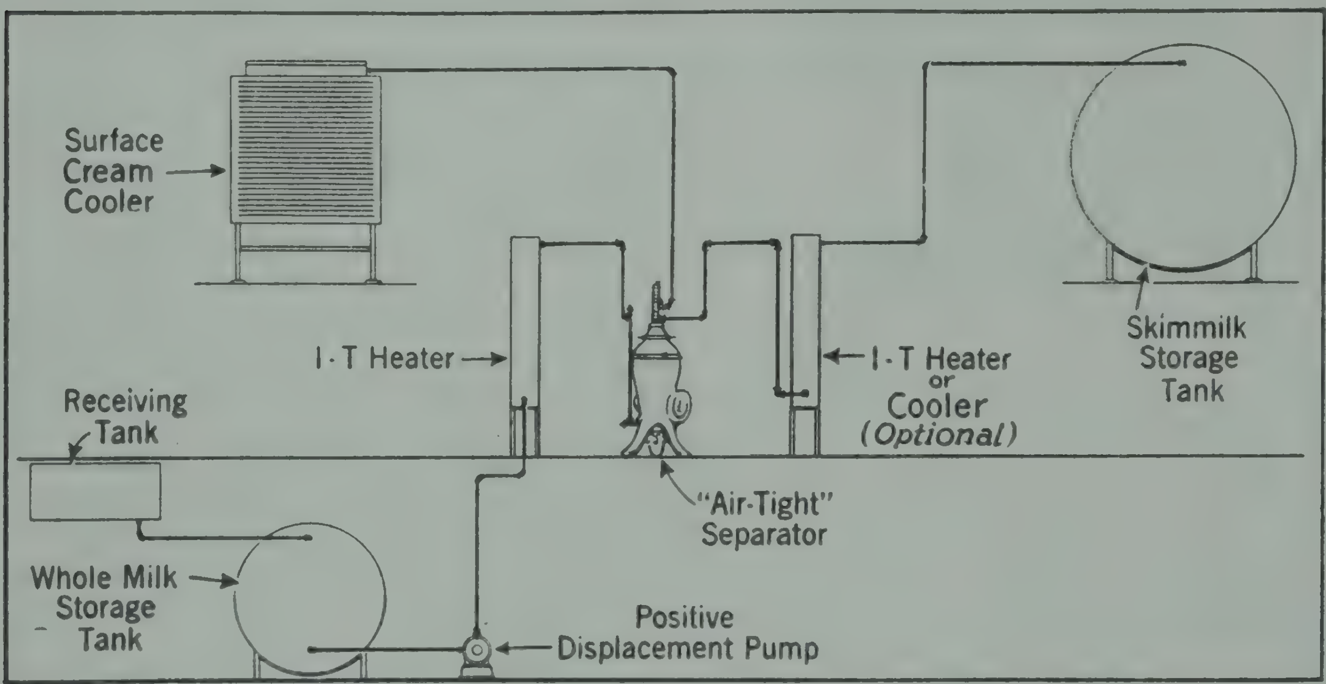


Fig. 25. Flow sheet for air-tight separator
Courtesy of De Laval Separator Co.

discs and providing more and thinner films of milk in the separating zone. This means longer travel while exposed to centrifugal force and less resistance against the movement of the fat globules in their migration to the neutral or quiescent zone. The absence of air eliminates the separation-hindering effect of the air. The fact that the incoming whole milk enters the separating zone of the bowl and does not pass through the cream layer, and that the cream is actually in the center of the bowl.

where it is protected against centrifugal agitation, preclude the possibility of any disturbance of the cream layer that might cause remixing of fat globules with the skim milk. These several factors manifestly operate in favor of high skimming efficiency.

The air-tight separator likewise has a remarkable and undeniably beneficial effect relative to the quality of the cream. Its operation sufficiently protects the fat globules from mutilation and the fat clusters from dispersion, to preserve the natural viscosity of the cream, such as resembles the superior properties of gravity cream. This effect is traceable to the following factors:

1. Making unnecessary the preheating of the milk to or above the melting point of the butter fat (above 100°F.) to insure high skimming efficiency, the fat globules and fat clusters are not disturbed prior to separation. This protection is further facilitated by the fact that the pump feeding the separator is a positive displacement type pump, and that the milk is preheated between pump and separator.

2. The pressure under which the milk reaches the separator and the small orifice (7/16") of the hollow spindle, cause it to enter the bowl at a high velocity that synchronizes with the speed of the revolving spindle and bowl. The milk is, therefore, not subjected to undue shock or concussion that would seriously disturb the physical system of the fat globules, leaving the fat clusters largely intact.

3. In addition, the cream leaves the revolving bowl from the center of gravity where it comes to rest concurrent with the revolving bowl. Here it is still under pressure and is released without impinging against stationary surfaces as may be the case with the open discharge type separator. The elimination of the necessity of pumping the cream after separation is an added protection to its body.

In further support of the theory of the preservation of the fat clusters in the operation of this separator, may be cited the reported experimental observation that the cream from the air-tight separator consistently yields a definitely lower bacteria count than cream from the open type separator. This suggests that the clusters of bacteria, likewise, are not dispersed to as great an extent in the air-tight, as in the open discharge machine.

In addition, the absence of air in the cream itself is beneficial to the body and assists in retarding flavor deterioration due to oxidation.

The Skim Milk Outlet.—As previously stated, the layer of milk nearest the periphery of the bowl contains the least fat and represents the skim milk. It is discharged either from the top or from the bottom of the bowl. Before it is permitted to leave the bowl, the skim milk is conducted from the periphery to near the center of the bowl, where it is discharged. For this purpose the topmost disc is covered by a special closing disc, the lower edge of which extends to near the wall of the bowl and the upper end terminates in a sleeve which extends into the neck of the bowl cover. This closing disc is spotted with spacer caulks on its upper surface, to provide a narrow passage between it and the bowl cover. The skim milk flows through this passage and leaves the bowl through one or more small openings or slots.

In the newer models, these skim milk discharge openings are bored at a trailing angle as explained under "Slotted Distributor Type Bowl." The purpose of carrying the skim milk to near the center of the bowl before it is permitted to escape to the outside, is to reduce the force with which it is discharged. In its passage toward the center the skim milk must overcome the centrifugal force. In some makes of separators the skim milk outlet is adjustable and provides the means of controlling the discharge and richness of the cream. By damming the skim milk outlet, the cream outlet yields more and thinner cream. By releasing the skim milk outlet, the cream discharge is diminished and the cream is richer.

The Cream Outlet.—The cream finds its exit at or near the center through the top or neck of the bowl cover. In all bowls except the air-tight, its entrance to the outlet is located slightly nearer the center than the centermost part of the skim milk outlet. In the case of the air-tight bowl the cream is located and leaves the bowl at the exact center.

In most separators the cream outlet or cream screw is adjustable. If located in the top of the bowl cover, the cream screw usually carries an eccentric orifice which is the cream outlet. This screw may be turned to place the orifice nearer to or farther from the center, thus securing less and richer

cream or more and thinner cream, respectively. If the cream screw is located in the side of the bowl cover neck, the distance from the center at which the cream escapes from the bowl is regulated by turning this screw farther in or out. In the air-tight bowl the amount and richness of the cream discharge is regulated by restricting or enlarging the outlet by means of a pressure type screw valve, the turning of which either dams up the cream at the outlet or releases it. In all separators except the air-tight, the adjustment of the cream outlet or skim milk outlet can be done only with the bowl at rest. The air-tight separator permits of adjustment without stopping the bowl.

Adjustment of Cream Screw to Regulate Proportion of Skim Milk and Cream, and to Control Richness of Cream.—As previously stated, the milk in the revolving bowl is forced to the side of the bowl, forming a vertical wall. The inner line of the milk in the bowl and of the skim milk in the skim milk tubes or skim milk space, forms a straight vertical line.

As more milk flows into the bowl, the wall of milk extends farther toward the center until the skim milk begins to discharge from the skim milk outlet. As the inflow of milk continues, the wall of milk in the bowl increases in thickness until the cream begins to escape through the cream outlet. Simultaneously the discharge of the skim milk increases. When the discharge of the skim milk and cream outlets equal the inflow of the milk, the thickness of the wall of the milk in the bowl becomes constant.

In some separators the proportion of skim milk to cream is controlled by the radius of discharge, i. e., by the relative distance of the two outlets from the bowl center; in others, by damming up the skim milk at the point of discharge. In the latter case, both skim milk and cream outlets are stationary and their size and position from bowl center are fixed and unchangeable. But here the bowl is equipped with a milk screw, the lower end of which extends to near the skim milk outlet. At this point the skim milk travels faster than the bowl. Hence the turning down of this milk screw causes the skim milk to dam up behind the screw. This in turn makes the skim milk escape through the skim milk outlet (slot) more rapidly and in larger volume. Hence a greater proportion of skim milk is discharged.

Supply Tank, Float and Discharge Pans.—As accessories to the bowl may be considered also the milk supply tank of the

hand separator, the receiving cup with float, and the milk and cream discharge pans.

The milk supply tank rests on an extension of the separator frame. It is used only in the case of hand separators. In factory machines the milk runs into the separator direct from the vat or heater, either by gravity or by means of a supply pump. The receiving cup is a part of the cover of the discharge pans. It accommodates the float, which device consists usually of a sealed, hollow tin bob acting as a regulator of the milk inflow. When the separator is fed too fast, the float rises on the surface of the milk in the receiving cup and closes a part of the milk outlet of the supply source.

Separators having bowls which discharge both their skim milk and cream at the top of the bowl, are equipped with a cream and a skim milk catch pan with discharge spouts. These pans rest on the separator bowl frame. The top pan discharges the cream, the bottom pan the skim milk.

The Driving Mechanism.—The parts of the separator which control the transmission of the motive power, differ with the type of motive power available in plants. Cream separators are either of the hand or small farm type, which may also be operated with a small motor or power attachment connected with a line shaft, or they are of the power or factory type.

Power Separators.—The first centrifugal separators were those used in the factories and which were operated by power. The factory machines, as far as the type and mechanism for the transmission of the motive power is concerned, may be divided into belt machines, turbine machines, and electrically-driven machines.

In the steam turbine-driven separators, in most cases, the lower end of the spindle carries a turbine wheel, which revolves in an enclosed turbine chamber of the separator frame and which contains a reduced steam inlet and a steam exhaust. The steam supply pipe is equipped with a valve to regulate the steam inlet, and for safety's sake it should carry, between the steam valve and the separator, a steam gauge. Most separators of this design today are also equipped with a steam governor which automatically controls the passage of steam to the turbine chamber for maintaining a uniform speed at the proper velocity of the bowl.

The electrically-driven separator is a later innovation. It is equipped with an electric motor which is a part of the separator and which requires no power transmission arrangement additional to that which forms a part of the separator.

Hand Separators.—In the case of the hand separator the power mechanism is a part of the separator proper. It, too, differs in details of arrangement with different makes of machines. The fundamental principle of the mechanism is to produce the relatively high number of revolutions which are required at the bowl (approximately from 6,000 to 7,000 R.P.M.), from the limited and relatively small number of turns of the crank shaft (about 45 to 60 turns per minute), which can be conveniently applied by hand. This is accomplished by transmission of the power by a series of gear wheels located between the crank shaft and the spindle of the bowl. The type of gears varies somewhat with different makes of machines. They may consist largely of helically cut worm wheels, set at a proper angle to mesh with a worm spindle on the top of which the bowl is supported.

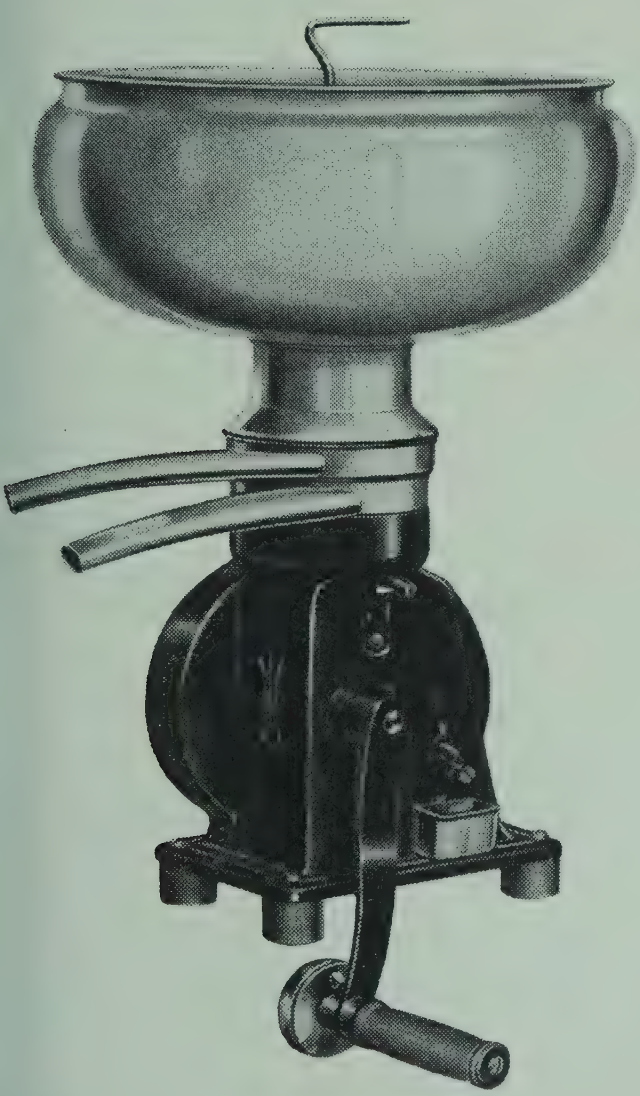


Fig. 26. Hand separator
Courtesy of De Laval Separator Co.

The successive multiplication in speed resulting from these transmissions depends on the difference in the number of cogs and the angle of pitch. The ratio relation between worm gears and spindle is so gauged that the proper bowl speed is attained when the crank is turned the number of revolutions per minute prescribed thereon.

It is obvious that the smoothness of running, as far as the transmission is concerned, is dependent on the regularity and state of preservation of the worm gear teeth. If these teeth are abnormally worn, or if one or more of them are broken, the

machine slips and jolts, making the proper operation of the separator impossible.

These facts further emphasize the importance of care in starting, running and stopping the separator, and in the use of bowl brakes. The crank shaft of most hand separators now on the market is provided with a ratchet which guards against shocks due to sudden stopping of the crank.

Systems of Oiling.—The system of oiling is a very important part of the machine and its operation. Absence of a proper and adequate system of oiling may cause undue friction on the wearing parts, which may result in misalignment and damage to the separator and unsatisfactory operation.

There are in use principally three systems of oiling, they are the "splash-oiling system," the "sight-feed cup oiling system" and the "open-hole oiling system." They vary in their application with the different makes of separators. Obviously that system is the best which is most nearly automatic, removes the sediment without permitting it to recirculate, and economizes oil.

In the "splash-oiling system" the gears and wearing parts are partly submerged in the oil, the oil usually being splashed by the lowest gear over the others and over the other wearing parts of the separator. In some separators provisions are made in the gear chamber for the draining of the grit and dirt, so that clean oil only circulates over the wearing parts. The "splash-oiling system" is completely automatic in its operation.

The "sight-feed cup oiling system" depends for its efficiency in continuously oiling the friction parts, on being so adjusted as to feed the oil slowly, and on being kept filled. In its operation care is required to keep the feed tubes open and free from clogging which may occur in cold weather when the oil becomes abnormally viscous, or congeals entirely. This oiling system may be considered semi-automatic.

The "open-oil-hole system" is obviously the crudest form of oiling the cream separator. It requires constant attention while the separator is used. Its lubrication is not uniform, it wastes oil, is mussy, and the holes readily become clogged with dirt, waste, and other obstructions. This system is not used extensively today.

Power Requirements of Cream Separators.—The amount of

power required to drive a separator at the requisite speed varies with the capacity of the machine. It also varies with machines of the same capacity but of different makes, and there is a considerable difference between the power required when empty and when loaded. The state of repair, kind of oil used, and efficiency of oiling are further factors which bear on the ease of running.

Factory separators of a capacity of about 5000 pounds per hour, when loaded, require about 2 H.P. at the start and until full speed is attained. After that, from seven-eighths to one H.P. is sufficient to maintain full speed. Farm separators of the usual capacity of about 350 to 500 pounds per hour require approximately from .063 to .16 H.P. when loaded.

Capacity of the Cream Separator.—The separator has two capacities, a pumping capacity and a skimming capacity. The pumping capacity refers to the volume of milk which the separator is capable of drawing into the bowl and of discharging through the skim milk outlet and the cream outlet, without causing the bowl to overflow. It is the skimming capacity, however, that is of chief importance and that is here referred to.

By the capacity of the cream separator is understood, therefore, the amount of milk the machine will skim clean per hour. Every cream separator is rated at a definite capacity; that is, it is built to separate a certain specified amount of milk in a given length of time. The farm separators range in capacity from about 150 to 1,200 pounds of milk per hour. For dairies with five to six cows a 350 to 400 pound capacity machine is recommended. The capacity of factory machines ranges from about 1,200 to 11,000 pounds of milk per hour. There is considerable difference in the relation of rated capacity to standard of skimming efficiency between different makes of machines. The rated capacity of some machines is high chiefly because the manufacturers of such machines are willing to sacrifice skimming efficiency.

The capacity of the separator must have a definite relation to the centrifugal force and to the manner of using this force, if the machine is to do efficient skimming. An increase in the throughput of any given separator hastens the passage of the milk through the bowl and shortens the time during which it is subjected to the centrifugal force. The maximum throughput

of a separator should, therefore, not exceed the amount of milk which can be efficiently skimmed in an hour.

Theoretically, the size of the skim milk and cream outlets of the bowl influence the capacity of the separator, for the larger these outlets, the more milk the separator is capable of taking in. If the bowl were not in motion and the discharge of skim milk and cream were dependent only on the mechanical overflowing of these parts, this hypothesis would be correct. In such case these parts would be completely filled.

But when the bowl is in motion such is not the case. The increased rapidity of the discharge due to the centrifugal force generated in the revolving bowl, greatly augments the capacity of the discharge parts, so that the skim milk and cream outlets are not completely filled and do at no time discharge skim milk and cream in accordance with their full capacity. This fact has been conclusively demonstrated by Eckles and Wayman,[2] who found that, under normal conditions, the skim milk tube does not run much over one half of its actual capacity.

Within reasonable limits, a change in the proportion of skim milk and cream delivered, as caused by a change in the position of the skim milk screw, cream screw, or milk screw, does not affect the capacity of the separator. In general, the richness of the cream delivered, therefore, has no material effect on the capacity of the separator.

The capacity of the separator is directly affected by the rate of inflow. When the rate of inflow drops below the designated capacity, less milk flows through the separator and more time is required to separate a given amount of milk. When the rate of inflow is increased beyond the designated capacity, more milk flows through the separator than its capacity calls for and less time is required to separate a given amount of milk. This latter fact is possible only because the skim milk and cream outlets are not filled to full capacity when the separator is operated under normal conditions. Hunziker[3] shows that the same volume of milk that under normal inflow required 7 minutes for separation, required 11 minutes in the case of a reduced inflow and 6 minutes in the case of an increased inflow.

The speed of the separator exerts a considerable influence on the capacity of the machine. The greater the speed the more rapid the exit of skim milk and cream, and the greater the throughput of the separator. Hunziker[3] shows that, when at

normal speed, it required 5 minutes to separate a given volume of milk, the same volume required 9.6 minutes at a speed reduced 25 turns of the crank below normal, and it required only 3.3 minutes at a speed increased 15 turns of the crank above normal.

The state of cleanliness of the separator may affect the capacity of the machine to a considerable extent and, in the case of an extremely bad condition, may clog the machine entirely. The formation of separator slime on the bowl wall reduces the diameter and thereby diminishes the centrifugal force, which, in turn, decreases the rapidity with which the milk passes through and out of the machine. The accumulation of foreign matter and clots also tends to diminish the size of the outlets and partly to block the passage of skim milk and cream.

CONDITIONS AFFECTING THE SKIMMING EFFICIENCY OF THE SEPARATOR

The exclusive purpose for which the cream separator has been devised is to skim milk. In its construction, efficiency to skim close was the dominant aim. This skimming efficiency has been accomplished to a very marked degree. An efficient cream separator, properly operated removes from about 98 to 99.5% or more of the butter fat contained in the milk, leaving in the skim milk approximately from 0.1% to 0.01% fat or less, as determined by the Babcock method.

In order to accomplish high skimming efficiency, the machine must be operated properly and in accordance with the directions furnished by the manufacturer. The chief factors which control the skimming efficiency of the cream separator are: Speed of machine, rate of milk inflow (throughput), and temperature of milk. In addition to these fundamental factors, other conditions such as adjustment of cream screw, smoothness of running, cleanliness of separator bowl, and condition of milk, may influence the per cent fat lost in the skim milk to some extent.

Effect of Speed of Separator on Skimming Efficiency.—The higher the speed, the greater is the centrifugal force and, other conditions remaining the same, the more complete is the separation. Every cream separator has a given, rated speed at which it will do its most efficient work. If the speed is reduced

below that required, the skimming efficiency will be lessened. A speed greater than the rated speed operates in the direction of increased skimming efficiency. However, in the better machines now available the rated speed represents the optimum of economical returns.

The speed of the bowl varies considerably with different makes of separators. Since, at a given speed, the centrifugal force increases with the increase of the diameter of the bowl, separators with wide bowls do not require as high a speed to develop the desired separating efficiency as separators with a narrow bowl.

Control of Speed of the Separator.—In the case of the hand separator, as used on the farm, the operator may time himself by counting the turns of the crank per minute. By doing this occasionally he soon learns the necessary rapidity of motion required to run the machine at full speed. Or he may use a metronome, which can be set to tick the exact number of turns required per minute. Some separators have a bell attachment striking the required number of revolutions per minute when the separator runs at full speed.

Table 12.—Effect of Speed on Skimming Efficiency of Separator. Averages of 48 Trials.

Skim Milk and Cream	Speed of Separator			
	10-15 R.P.M. Above Normal % Fat	Normal % Fat	10-15 R.P.M. Below Normal % Fat	20-30 R.P.M. Below Normal % Fat
Skim Milk	.029	.029	.120	.210
Cream	32.00	28.50	26.00	23.00

Automatic speed indicators are particularly valuable in the operation of the hand separator on the farm. Table 12 shows the loss of fat in skim milk due to operating the separator at too low a speed.

Effect of Rate of Throughput on Skimming Efficiency.—The rate of inflow has a very marked influence on the completeness of the separation. If the rate of inflow is forced beyond the specified capacity of the separator, the skimming efficiency decreases. This is due to the fact that the milk passes through the separator so rapidly that it is not exposed to the centrifugal

force long enough to undergo complete separation. Overfeeding the separator also is accompanied by the danger of overflowing the bowl and loss of milk. A reduction below capacity of the amount of milk passing through the separator is of no special advantage; it fails to appreciably increase the skimming efficiency and it prolongs the process of separation. These facts were experimentally demonstrated by the Purdue Agricultural Experiment Station,[3] as shown in Table 13.

Table 13.—Effect of Rate of Inflow on Per Cent of Fat in Skim Milk

	Large Inflow		Normal Inflow		Small Inflow	
	Per Cent of Fat		Per Cent of Fat		Per Cent of Fat	
	Cream	Skim Milk	Cream	Skim Milk	Cream	Skim Milk
	22.	.155	....	....	30.5	.025
	23.	.165	28.	.025	31.	.02
	22.5	.13	28.	.02	28.	.02
	22.	.14	28.	.035	28.	.03
	24.	.15	28.	.03	31.5	.03
	26.	.13	32.	.03	32.	.035
Average...	23.	.145	29.	.028	30.	.027

Control of Throughput.—The inflow of milk to the separator may be regulated by various contrivances used with hand and power machines. The most common regulator in use consists of a float which operates in the receiving cup, or milk reservoir, located directly over the bowl, as explained earlier in this chapter.

In all separators except the air-tight, the rate of inflow is affected to an appreciable extent by the depth of the milk in the supply tank. The fuller the milk supply tank the greater the pressure of the milk on the float and the more milk will flow into the bowl. In the case of the farm separator, properly operated, variations in the rate of inflow caused by variations in the fullness of the supply tank are not sufficient to seriously influence the skimming efficiency, but they may cause an appreciable effect on the richness of the cream. Undue crowding of the machine and sacrificing of skimming efficiency, due to the pressure of the milk above the bowl, frequently occur, however, when the separator is fed direct from a vat or tank, as is often the case when the supply vat is located at a considerable eleva-

tion above the separator. In the air-tight separator the capacity and the throughput are controlled by a positive-set flow to the machine.

Effect of Temperature of Milk on Skimming Efficiency.—Exhaustive skimming requires that the milk have a temperature of near, or above, that of the animal body, which is approximately 100°F. The freshly-drawn milk is in ideal condition for exhaustive skimming. Such milk is relatively fluid and its fat globules are still present in the form of liquid butter fat.

In the case of milk which has never been allowed to cool to a temperature of or below the solidifying point of butter fat (70°F. or below), a drop in temperature to 85°F. or even 80°F., does not seriously diminish the skimming efficiency. If the temperature is lowered to 70°F. or below, however, the loss of fat in the skim milk increases rapidly. When milk so cooled is subsequently warmed to 80°F.—85°F. the fat globules are still largely in a solid state and the skimming efficiency remains comparatively low.

The manner of heating and the temperature to which heated, are of further importance in that exposure to too hot a heating surface, or heating to too high a temperature causes the albumin to precipitate. This precipitate hampers freedom of movement of the fat globules and interferes with completeness of fat separation.

The viscosity of the milk also has some influence on the readiness of fat separation. Since at higher temperatures the milk becomes more fluid, such temperatures tend to improve the skimming efficiency.

On the farm the simplest way to have the milk at the right temperature for separation, is to separate immediately after each milking. This practice does away with the bother of artificially heating the milk before separating, for which the average farm is not properly equipped, but which would be necessary, especially in winter, if the milk were held over from the previous milking or previous day. The best condition of milk for separation is that when freshly drawn.

Effect of Position of Cream or Skim Milk Screw on Skimming Efficiency.—As already explained, the purpose of the cream screw, skim milk screw, or milk screw, is to regulate the ratio of cream to skim milk and to control the richness of the cream.

Most makes of separators permit of a rather wide range of fat content in cream, without materially sacrificing skimming efficiency, although the tendency is always in the direction of diminished skimming efficiency when attempting to secure abnormally rich cream.

Effect of Smoothness of Running on Skimming Efficiency.—The separator cannot be expected to do efficient work unless it runs smoothly. When the bowl revolves smoothly and without jarring, the skim milk and cream escape from the machine separately. If the machine trembles and jars, a portion of the cream and skim milk may again become mixed by the vibration of the bowl, causing a relatively large amount of fat to escape with the skim milk, thus reducing the skimming efficiency of the separator.

The trembling of the bowl may be due to any one or more of the following conditions: Shaky foundation, machine not setting level, spindle sprung, internal contrivances of bowl damaged or not properly placed or incomplete, worn-out bearings, loose bushings, and excessive speed.

The separator, while it should be fastened securely to its foundation, should not be screwed down too rigidly for smooth running. A certain amount of "give," or "resonance" is necessary in order to insure smooth running.

Effect of Cleanliness of Separator on Skimming Efficiency.—Milk, even in its best condition, contains a certain amount of impurities such as dirt, dust, and other foreign matter gaining access to it during its production. This, together with particles of viscous nitrogenous matter naturally present in milk, collects in the separator bowl, forming the so-called separator slime. It is deposited largely on the walls of the bowl and between the internal contrivances.

This slime may also impede the free passage of milk and cream within the bowl, thereby reducing the diameter, centrifugal force, and capacity of the bowl, lowering its skimming efficiency and causing excessive loss of fat. This loss is greatest with milk in poor physical condition. The results of experiments by Hunziker[4] show that the fat loss in the skim milk by the use of unclean separators was approximately three times as great as when using a clean separator bowl.

Guthrie and Supplee[5] found that, within reasonable limits,

deposits of separator slime in the bowl do not materially interfere with the skimming efficiency of the machine. They conclude that only when the bowl fills up with separator slime to the extent of clogging the passages, does the efficiency of separation suffer.

In commercial separation of milk, where the separator often is in continuous operation for several hours, the accumulation of separator slime is frequently very great, and this in turn is bound to seriously diminish the skimming efficiency of the machine.

Effect of Condition of Milk on Skimming Efficiency of the Separator.—Milk in poor physical condition, such as milk containing a relatively large amount of impurities, or milk which is old and partly sour or curdy, tends to lower the skimming efficiency, largely because it augments the amount of separator slime which collects in the bowl; this in turn impedes the free passage of milk and cream and causes excessive loss of fat.

If the milk is curdy the danger of incomplete separation is augmented by the fact that each particle of curd locks up a small amount of fat, and the curd passing into the skim milk on account of its greater specific gravity, carries this fat with it. If it is necessary to run curdy milk through the separator, the milk should be poured from one can to another, or stirred, sufficiently to break up the curd as finely as possible. If such milk must be separated it is advisable to slightly underfeed the separator.

THE RICHNESS OF CREAM AND WHY CREAM TESTS VARY

The subject of richness of cream and the problems related to it are of vital importance in the operation of the commercial creamery. They have to do not only with the effect on quality of butter and economy of operation, but especially also with the complexities involved in satisfying the farmer with the returns for his cream, and in gaining and holding his confidence in the creamery's integrity.

The Ideal Richness of Cream for Churning.—Cream when ready to be churned should have a fat content of about 33%. Before the cream reaches the churn it suffers considerable dilution due to the addition to it of water in the form of rinsings of cans, forewarmers, pasteurizers, vats, etc., and where butter culture is used, there is an additional dilution due to the skim

milk contained in the culture added to the cream. These dilutions vary a great deal but may average about 15%, that is 100 pounds of cream received may increase in volume during its journey from forewarmer to churn so it will weigh 115 pounds at the churn.

In order for the cream to have approximately the desired richness when churned, therefore, the cream arriving at the creamery should average from about 35% to 45% fat.

Disadvantages of Too Thin Cream.—The economic disadvantages to the farmer of producing excessively thin cream are self evident. The thinner the cream the smaller the amount of skim milk left on the farm for feeding purposes, the greater the volume of cream that must be handled, cooled and transported, and the higher the cost of shipping cream per pound of butter fat. Thin cream has the further disadvantage of deteriorating more rapidly than cream of greater richness. It may, therefore, result in a sacrifice in price received by the farmer.

As far as the creamery is concerned the chief objections of thin cream are: tendency of poor quality upon arrival, excessive loss of fat in buttermilk due to larger volume of buttermilk, increase of time required for churning, decrease of capacity of vats, pasteurizers, and churns, increase in labor of handling the cream, more heat and cold expended for heating and cooling, and less advantageous use of butter culture. It is uneconomical for the farmer to sell and for the creamery to buy thin cream.

Disadvantages of Too Rich Cream.—Because of the economic disadvantages of excessively thin cream, and as the result of the educational efforts to induce the farmer to produce a richer cream, the fat content of the cream received by the majority of creameries today averages materially higher than it did in the early days of the farm cream separator system. In certain sections of the country, especially in the southern tier of the dairy belt, the pendulum has swung to the opposite extreme, resulting in the production of excessively rich cream, such as cream testing over 45% and as high as 60% fat.

This new situation is equally as objectionable in the case of cream intended for butter manufacture, as the low testing cream. Cream testing over 45% fat is difficult to handle, both on the farm and in the creamery. It has a tendency to clog the separator and cause excessive loss of fat in the skim milk.

Further loss is encountered in transferring such cream from pail to can. The creamery experiences difficulty in securing a representative sample from such cream because it does not stir and mix readily. This difficulty is aggravated and becomes a serious problem during cold weather. Cream of excessive richness coming from cows fed heavily on cottonseed meal is especially firm, and hard to handle.

Importance of Uniform Richness of Consecutive Shipments of Cream.—The cream test reported by the creamery to its patrons is a potential factor in swaying the cream producer for or against the reporting creamery. There is perhaps no one factor, with the possible exception of open dishonesty, that is so potent in its tendency to demoralize and disorganize the cream supply territory of the creamery, as a repetition of variations in the reported cream tests of successive deliveries of cream from the same patron, especially when the trend of the fluctuations is downward. The patron naturally believes in the dependable uniformity of performance of his separator. He expects the same separator, without change in the adjustments of the cream screw or skim milk screw, to deliver cream of the same richness at each separation. Therefore, if the cream tests of successive shipments vary, he questions the correctness of the creamery tests and is inclined to accuse the creamery of carelessness or unfair dealings.

In some instances of irregularities in reported cream tests these suspicions may be justified. The possibility of errors in cream testing, as in all human endeavor, is ever present. However, the creamery operator's appreciation of the economic importance of correct cream tests is sufficiently compelling to provide such safeguards as to insure a reasonably dependable standard of accuracy. Accidental errors in cream tests are, in fact, confined to isolated exceptions. Unscrupulous practices in the manipulation and reporting of the cream test also do occur occasionally. Such dishonesty is deplorable and cannot be too strongly condemned, nor too severely punished when discovered. They, too, are the exception and are an insult to the general high standard of honesty of the rank and file of creamery operators.

The great majority of recurring variations in cream tests of successive deliveries of the patron's cream are not due to

incorrect tests, but to corresponding variations in the richness of the cream incident to the operation of the cream separator and to the handling of the cream on the farm. The following are the major factors relative to the operation of the farm separator, that control or influence the richness of the cream: Position of cream screw or skim milk screw, richness of milk, speed of separator, rate of inflow, temperature of milk, amount of water or skim milk used to flush the bowl, cleanness of separator bowl, and condition of holding cream on the farm.

Effect of Cream Screw or Skim Milk Screw on Richness of Cream.—The relation of the position of the cream screw or skim milk screw, to the proportion of cream to skim milk and to the richness of the cream was discussed earlier in this chapter.

Fundamentally, any change in the separator which will alter the relative amounts of skim milk and cream, will influence the per cent of fat in the cream. These devices, the skim milk screw and the cream screw, are very sensitive adjustments. Only a slight turn (¼ turn) of the screw is sufficient to bring about a very appreciable change in the per cent fat in the cream.

Effect of Richness of Milk on Richness of Cream.—The richness of the milk directly influences the richness of the

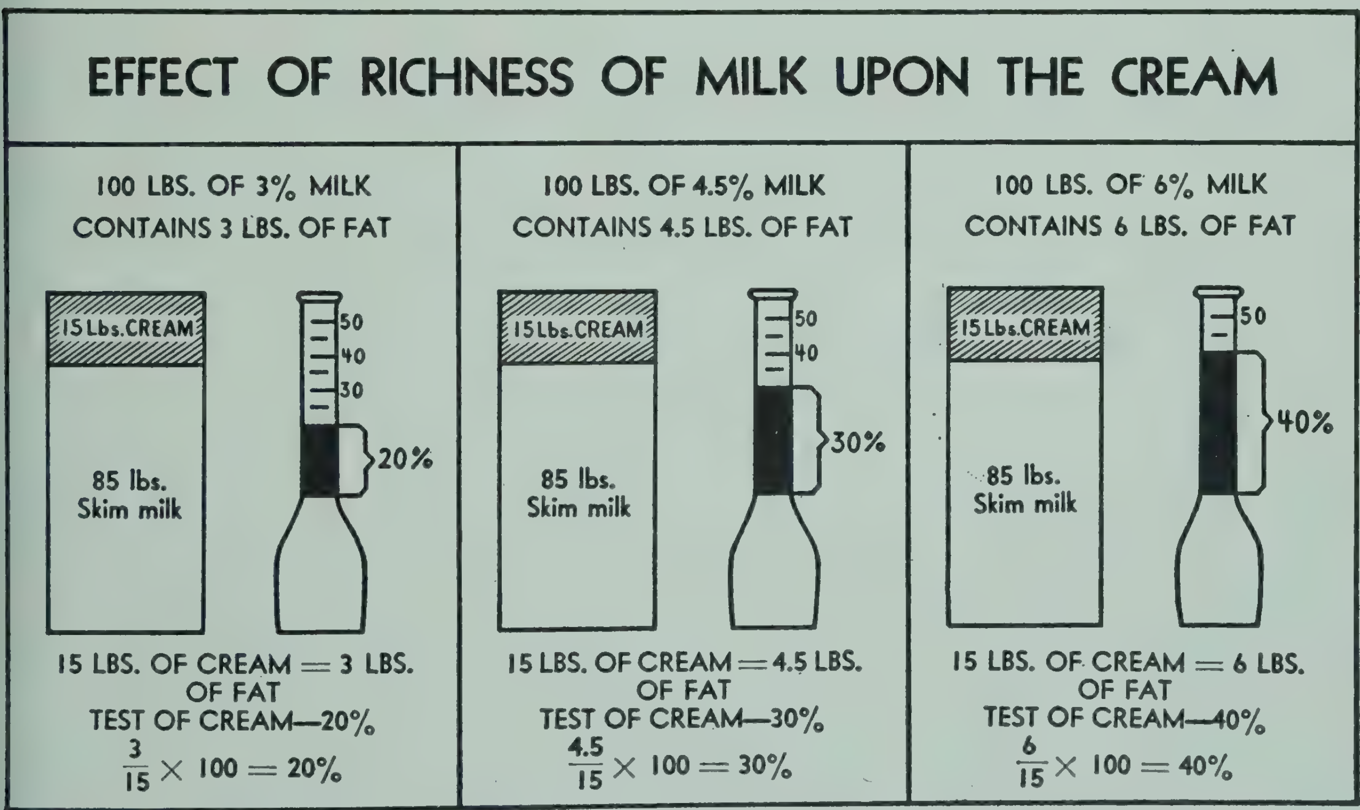


Fig. 27.[3]

cream; in fact, the per cent of fat in the cream stands in direct proportion to the per cent of fat in the milk separated.

With the cream screw set to deliver a certain definite richness of cream, and all other conditions normal, the separator will deliver a definite ratio of skim milk to cream. Changes in the richness of the milk cannot alter it, no matter how rich or how poor the milk. But, since practically all of the fat goes into the cream, the cream from the separation of rich milk contains more fat than that from poor milk. This fact is graphically illustrated in Fig. 27.

Fig. 27 shows that with a ratio of skim milk to cream of 85 to 15, and with all other conditions constant, 3% milk produces 20% cream, 4.5% milk produces 30% cream, and 6% milk produces 40% cream. The correctness of this rule is further demonstrated by results of separator experiments conducted by Hunziker,[3] as summarized in Table 14. Similar results were reported by Eckles and Wayman,[2] and by Guthrie and Supple.[5]

Table 14.—Showing Effect of Richness of Milk on Richness of Cream

Experiment No.	Milk			Time of Separation, Min.	Cream			Skim Milk
	Lbs.	Fat %	Fat Lbs.		Lbs.	Fat %	Fat Lbs.	Lbs.
Milk Testing 3% Fat								
I	50	3	1.5	7	6.25	19	1.18	45
II	50	3	1.5	7	6.5	20.5	1.33	46
III	50	3	1.5	7	6.5	20.5	1.33	46
Average	50	3	1.5	7	6.42	20	1.28	46
Milk Testing 4.5% Fat								
I	50	4.5	2.25	7	6.25	34	2.12	45.5
II	50	4.5	2.25	7	6.5	32	2.08	44.8
III	50	4.5	2.25	7	6.25	31.5	1.96	44.7
Average	50	4.5	2.25	7	6.3	32.5	2.05	45
Milk Testing 6% Fat								
I	50	6	3	7	6.5	40.7	2.65	44
II	50	6	3	7	6.5	40	2.6	44
III	50	6	3	7	6.5	36	2.34	44
Average	50	6	3	7	6.5	39	2.53	44

Effect of Speed of Separator on Richness of Cream.—The higher the speed of the separator the higher the per cent of fat in the cream. This rule applies in the case of most separators and under most conditions. The influence of speed on the richness of the cream is largely due to the direct effect of the speed on the ratio of skim milk to cream.

The higher the speed, the greater the centrifugal force and the more rapidly will the skim milk leave the bowl. An increase in speed therefore increases the capacity of the skim milk discharge. This means less milk for the cream outlet and consequently richer cream. A decrease in speed lessens the centrifugal force, retards the escape of skim milk, reduces the capacity of the skim milk outlet, and more milk has to be discharged through the cream outlet. The cream, therefore, is thinner. In the following table are summarized results of experiments[3] showing the effect of separator speed on richness of cream.

Table 15.—Effect of Speed of Separator on Richness of Cream

Experiment No.	Time of Separation, Min.	Cream			Skim Milk		
		Lbs.	Fat %	Fat Lbs.	Lbs.	Fat %	Fat Lbs.
			Low Speed				
I.......	9	9.5	11	1.05	40.3	2.8	1.1
II......	9	9.5	10	.95	39.6	2.9	1.15
III.....	9	9.7	11.5	1.12	39.8	2.5	1
Average.	9	9.6	10.8	1.04	39.9	2.73	1.08
			Normal Speed				
I.......	5.5	5.2	41.5	2.17	44.8	.04	.02
II......	7	4.7	45	2.12	44.8	.07	.03
III.....	7	5.1	40	2.04	44.5	.07	.03
Average.	6.5	5	42.2	2.11	44.7	.06	.03
			High Speed				
I.......	6	3.3	65.5	2.1	46.5	.10	....
II......	6.5	3.5	59.5	2.08	45.9	.03	.01
III.....	6.5	3.1	65	2.02	46.6	.06	.03
Average.	6.33	3.3	62.7	2.07	46.3	.03	.01

These facts apply to all separators and under all conditions where the skim milk and the cream exits are so adjusted that the skim milk outlet is farther from the center of the bowl than the cream outlet. This is the case with most separators and under most conditions.

Additional factors which may enter into the causes of richer cream, are: the reduced relative friction in the skim milk outlet due to the larger volume of skim milk discharged, and the increased relative friction in the cream outlet due to the greater viscosity of the richer cream. Furthermore, the more complete separation in the case of high speed may in part at least be conducive to richer cream. These facts are graphically illustrated in Fig. 28.

However, the effect of speed varies to some extent with the richness of the cream for which the separator is set. When set for rich cream there is a greater difference in the per cent of fat of the resulting cream between high speed and low speed than when set for thin cream. This is due to the fact that when the machine is adjusted to produce rich cream, the relative difference between the distance of the skim milk and cream outlets from the center of the bowl is proportionately greater, the proportion of skim milk discharged is larger, less milk is left to pass out with the cream, the cream is richer, and the influence

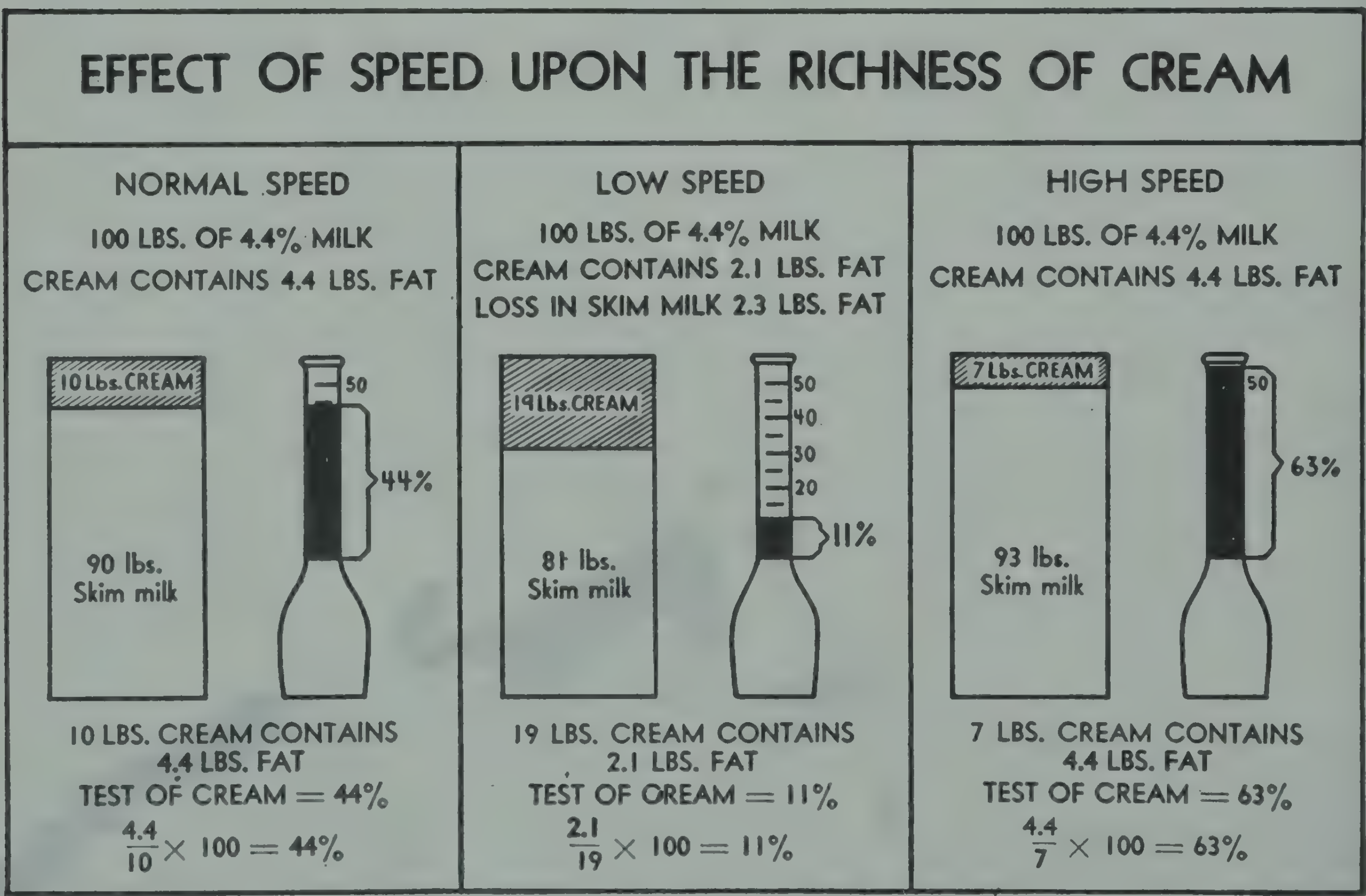


Fig. 28.[3]

of speed is greater than when the separator is set for thin cream. When set for thin cream the relative difference between the distance of the skim milk and cream outlets from the center is smaller, and there is less variation in the richness of the cream due to changes in speed.

Effect of Rate of Throughput on Richness of Cream.—The rate of inflow exerts a marked influence on the richness of the cream, as shown in the Table 16. The richness of cream increases as the rate of inflow decreases, and vice versa. This is due to the fact that when the rate of inflow is increased, the discharge of the cream outlet increases proportionately more than the discharge of the skim milk outlet, while a decrease in the inflow causes a greater decrease in the discharge of the cream outlet than in that of the skim milk outlet. The effect of changes in the rate of inflow on the cream test is graphically shown in Fig. 29.

Table 16.—Effect of Rate of Inflow on Richness of Cream

Experiment No.	Milk			Time of Separation, Min.	Cream			Skim Milk		
	Lbs.	Fat %	Fat Lbs.		Lbs.	Fat %	Fat Lbs.	Lbs.	Fat %	Fat Lbs.
Small Inflow										
I.......	50	4.3	2.15	11	2.86	70	2.02	46.7	.05	.02
II......	50	4.4	2.2	11	3.12	68	2.12	46.4	.12	.06
III.....	50	4.8	2.4	12	3.42	71.5	2.44	46.3	.08	.04
Average.	50	4.5	2.25	11.3	3.13	70	2.19	46.5	.08	.04
Normal Inflow										
I.......	50	4.3	2.15	7	5.5	37.5	2.06	44.2	.1	.04
II......	50	4.4	2.2	7	5.37	40	2.15	44.1	.05	.02
III.....	50	4.8	2.4	7	4.37	58.5	2.55	45.5	.03	.01
Average.	50	4.5	2.25	7	5.08	44.3	2.25	44.6	.06	.02
Large Inflow										
I.......	50	4.3	2.15	6	4.5	23.5	1.06	45.1	.25	.11
II......	50	4.4	2.2	6	7.75	26.5	2.05	42.1	.27	.11
III.....	50	4.8	2.4	6	4.86	51.7	2.51	44.7	.05	.02
Average.	50	4.5	2.25	6	5.70	32.8	1.87	44	.19	.08

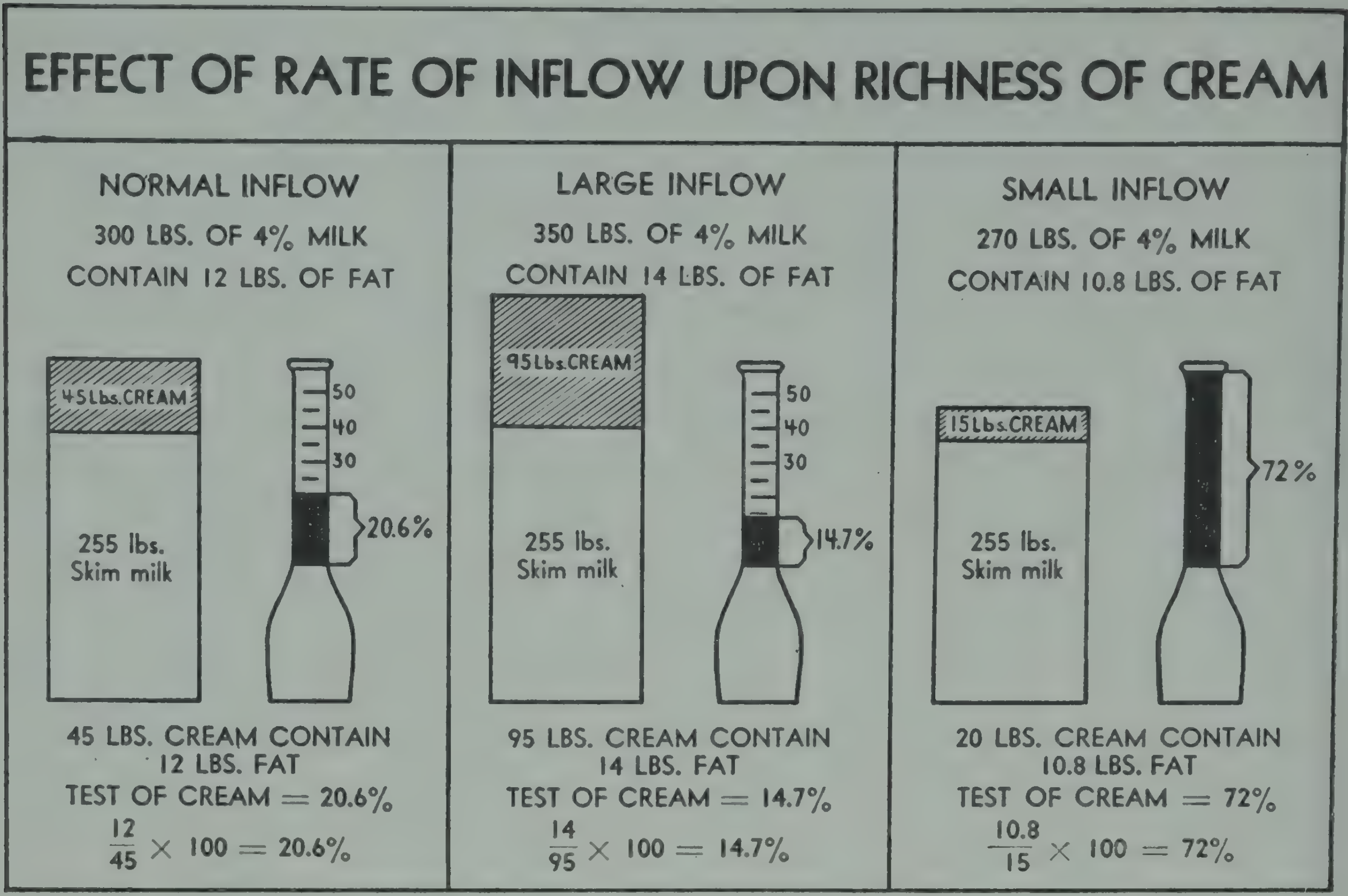


Fig. 29.[3]

Table 17.—Showing Effect of Temperature of Milk on Richness of Cream

Experiment No.	Time of Separation, Min.	Milk Lbs.	Milk Fat %	Milk Fat Lbs.	Cream Lbs.	Cream Fat %	Cream Fat Lbs.	Skim Milk Lbs.	Skim Milk Fat %	Skim Milk Fat Lbs.
Normal Temperature—90° to 95° F.										
I......	7	50	3.8	1.9	9	17.5	1.58	41	.03	.01
II.....	5	31.5	4.1	1.29	4.5	28	1.26	27	.03	.01
III....	8	50	4	2	9.7	20.5	2	40.9	.02	.01
IV.....	8.5	50	4	2	10.1	20	2.02	39.8	.01	....
V......	7.5	50	4	2	10.1	20	2.02	40.3	.01	....
Average	7.2	46.3	3.98	1.84	8.68	21.2	1.78	37.8	.02	.01
Low Temperature—50° to 60° F.										
I......	9	50	3.8	1.9	2	32.5	.65	48	1.50	.72
II.....	7	32	4.1	1.31	1.5	43	.65	28.5	2.10	.63
III....	7.5	50	4	2	7.2	27	1.94	43.6	.05	.02
IV.....	7.5	50	4	2	7.3	28	2.04	44.3	.03	.01
V......	7.5	50	4	2	7.2	28	2.02	44.1	.05	.02
Average	7.6	46.4	3.98	1.84	5.04	31.7	1.46	41.7	.75	.28

Effect of Temperature of Milk on Richness of Cream.—The temperature of the milk influences the richness of the cream obtained from the separator to a marked degree, as shown by Hunziker[3] and summarized in Table 17, and illustrated in Fig. 30.

The experimental results summarized in the above table show that cold milk yields richer cream than warm milk. The

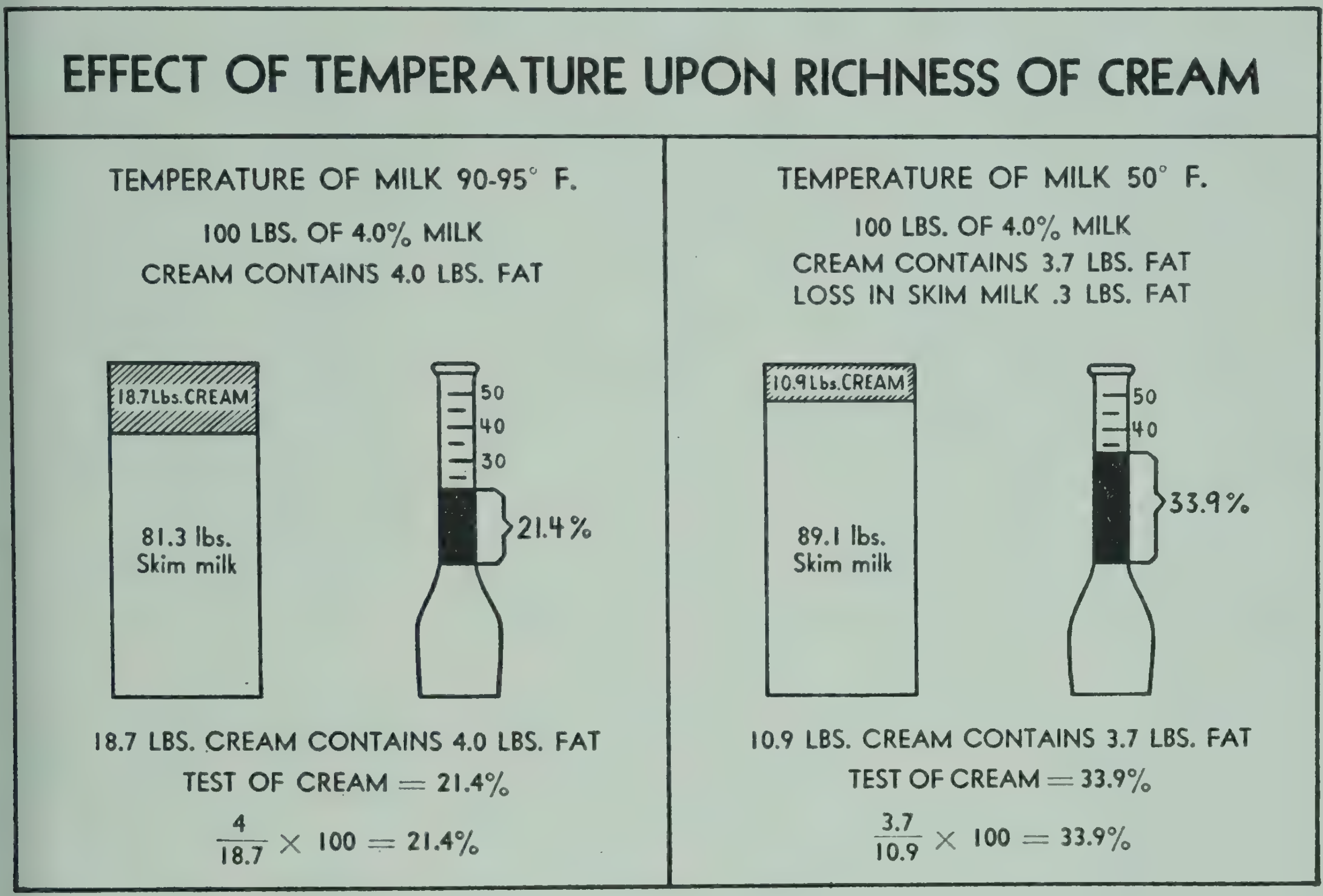


Fig. 30.[3]

cream from cold milk averaged 31.7% fat, while the cream from milk separated at 90° to 95° F. averaged 21.2% fat. The difference would probably have been considerably greater, had it not been for the excessive loss of fat in the skim milk from the cold milk, which reduced the amount of fat supplying the cream discharge.

Effect of Amount of Water or Skim Milk Used to Flush the Bowl on Richness of Cream.—The amount of water or skim milk used to flush out the separator bowl has a very marked effect on the richness of the cream as shown in Table 18. Unless it is regulated so as to use a uniform amount at each separation, the fat content of the cream of successive separations is bound to show wide variations.

It is very desirable that the bowl be properly flushed after each separation. This removes most of the remnants of milk and cream, and loosens the separator slime in the bowl, making subsequent washing more easy. In order to accomplish this, run water into the bowl until the discharge appears watery.

Table 18.—Effect of Amount of Water Used to Flush Bowl on Richness of Cream[3]

Experiment No.	Amount of Water Used to Flush Bowl			
	None	Same as Capacity of Bowl	Till Cream Discharge Was Watery	Twice the Amount Needed for Watery Cream Discharge
	Fat %	Fat %	Fat %	Fat %
I	32	32	31	29
II	30	30	29	28
III	58	56	51	48
IV	31	31	30	29
Average	37.8	37.3	35	33.5

Effect of Slime in Bowl of Separator on Richness of Cream.—Experiments conducted by Guthrie and Supplee[5] show that deposits of slime in the bowl do not have any appreciable effect on the richness of the cream so long as the slime does not clog the passages.

Effect of Souring on Richness of Cream.—There appears to prevail among cream producers in some localities the erroneous belief that sour cream yields a higher fat test than the same cream when sweet. This belief has led to the deplorable practice of holding the cream on the farm longer than necessary and under temperature conditions favoring rapid souring and causing serious depreciation in quality, due to fermentation and spoilage.

Hunziker, Cordes and Nissen[6] investigated the effect of souring on the cream test by a carefully conducted experiment, and demonstrated conclusively that the souring of cream does not increase the fat test; but when the conditions under which the cream is permited to sour also caused the simultaneous evaporation of moisture from the cream, the fat test increased.

That this is due to evaporation of moisture from the cream is shown in Fig. 31. This can of cream was held overnight at room temperature with lid on tight. Upon opening the can the following morning the lid was covered with a multitude of beads of water. In a sealed can this moisture returns to the cream, avoiding loss of weight and preventing increase in test. In an open can the moisture escapes, causing loss in weight and increase in test.

Fig. 31. Evaporation of moisture from cream, as indicated by visible beads of moisture on can lid

Without such evaporation there is, and there can be, no increase in the fat test. The increase in fat test, when it occurs, is directly proportional to the loss of weight in pounds of cream. The increase in the test, therefore, does not alter the pounds of fat for which the farmer gets paid. The amount of fat in the can remains constant. Sour cream contains no more fat than sweet cream.

While nothing is gained by souring the cream on the farm, much may be lost. Souring depreciates the quality of the cream and brings smaller returns wherever the cream is paid for on the basis of quality, as it should be. The practice of souring the cream on the farm decreases its market value. It diminishes the returns to the farmer, and it is a detriment to the entire butter industry.

Summary of Why Cream Tests Vary.—Assuming that the buyer of cream thoroughly mixes the cream so as to insure samples that are representative of the richness of the cream in the can, and that he conducts his tests accurately and honestly, variations in the fat test of cream of different shipments from the same patron are attributable and may be due to any one or more of the following factors:

1. Change in richness of herd milk. This may be caused by cows drying-up and fresh cows coming-in. In this case the tendency is toward a drop in the richness of the herd milk and a corresponding drop in the cream test. The addition to or taking out of the herd, of cows producing high or low testing

milk will have a similar effect. It will raise or lower the cream test, respectively.

2. The fat test of cream will always vary in the case of cream separated by the gravity system of creaming.

3. Tampering with the cream screw or skim milk screw in the separator bowl is bound to cause large fluctuations in the richness of the cream and in the fat test.

4. Irregularities in the operation of the farm cream separator will always cause variations in the fat test. High speed, small rate of throughput, and low temperature of milk, increase the test and produce less pounds of cream. Low speed, large milk throughput, and high temperature of milk, decrease the fat test and produce more pounds of cream. The more water or skim milk that is used for flushing the bowl, the lower the fat test of the cream.

5. Holding the cream at a high temperature in an unsealed can will cause increase in test and corresponding shrinkage in volume. It does not increase nor alter the pounds of fat in the can.

Directions for Preventing Variations in Cream Tests.—Set the cream screw or skim milk screw so as to deliver the desired richness of cream, or cream testing from 35% to 40% fat. When once set, leave it alone. Run the separator at each skimming uniformly at the proper speed, with the normal rate of throughput, using float, with the milk at the proper temperature—"cow warm"—and flush the bowl out with just enough water or skim milk to make the skim milk discharge appear watery. Cool the cream and keep it in cold water. Do not store in warm place. Souring does not increase the pounds of fat.

Attention to the above precautions in the operation of the farm separator will make for uniformity of richness of cream and of cream tests, but it will obviously not prevent fluctuations in the cream test that are due to seasonal and local variations in the richness of the milk used for separation.

REFERENCES

1. BECKMAN, H. C., De Laval Separator Co., by conference, (1927).
2. ECKELS, C. H., and WAYMAN, H. S., Mo. Agr. Expt. Sta. Bul. 94, (1911).
3. HUNZIKER, O. F., Purdue Agr. Expt. Sta. Bul. 150, (1911).
4. HUNZIKER, O. F., Purdue Agr. Expt. Sta. Bul. 116, (1906).
5. GUTHRIE, E. S., and SUPPLEE, G. C., N. Y. (Cornell) Agr. Expt. Sta. Bul. 360, (1915).
6. HUNZIKER, O. F., CORDES, W. A., and NISSEN, B. H., N. Y. Prod. Rev. p. 312, (1927).

CHAPTER VIII

BUYING MILK AND CREAM

Systems of Buying Milk and Cream.—The change from making butter on the farm to the manufacture of butter in the creamery, the development of diverse types of creamery organizations according to local conditions, the increased diversity of manufactured dairy products, and the growing keenness of competition among creameries for the raw material, milk and cream, have resulted in the development of numerous distinct systems of buying milk fat from the farmer. These systems may be conveniently grouped under four headings; namely, door deliveries of milk and cream; milk and cream routes; skimming stations and cream stations; and the direct shipper system.

While some creamery organizations have adopted and operate one system exclusively and buy all their raw material by that system, most creameries operate a combination of two or more of the several systems mentioned above.

THE DOOR DELIVERY SYSTEM

In this system the milk or cream is hauled by the farmer direct to the creamery.

Advantages of Door Deliveries.—This system has the advantage that the creamery comes in constant and personal contact with its patrons. Any disputes arising over quality, weights or tests, can be readily and understandingly explained, and usually satisfactorily settled. Misunderstandings are infrequent, because the two contracting parties know each other. In case of disputes over quality, joint inspection of the cream by patron and creamery operator facilitates agreement. In case of dissatisfaction with weights or tests, the weighing and testing may be done in the presence of the patron, giving him an opportunity to convince himself of the accuracy of the work.

Again, the farmer who is near enough to the creamery to deliver his own cream, usually also brings other farm produce to town at fairly regular intervals (at least once or twice per week, or oftener). He therefore does not have to hold his cream

on the farm unduly long for reasons of economy of transportation. Coming to town anyway with diverse farm produce, he can bring the cream along, whether he has a full can or not. This insures reasonably frequent delivery. The creamery thus is in a position to secure fairly fresh cream. Likewise, if the quality is not what it should be, the defect and its probable cause may be explained and advice for improvement and for means to prevent recurrence may be given at the platform, direct to the patron himself.

The factors of economy of door delivery and of potentially favorable conditions to insure freshness and quality of cream are of sufficient importance to merit efforts on the part of every creamery to develop the possibilities of its door deliveries to the fullest extent feasible under its local conditions. Door delivered cream usually nets the farmer higher returns than any other system of cream procurement.

Limitations of Door Delivery System.—The greatest drawback to this system lies in the fact that it limits the cream supply territory to a narrow radius. Its further extension is limited even under the stimulus of good roads and the increasing use of automobiles on the farm. A radius of 15 miles is generally the limit of door-delivered cream. If the distance from farm to creamery is greater, there is usually a market for the farm produce in some nearby town, and the tendency is for the cream to go there, too. The radius of direct deliveries may be extended somewhat by exchange of deliveries between producers within the same neighborhood. This system is adapted largely only in sections of the country where the dairy industry has reached a high state of development, where dairying is the principal business, where the herds are of good size and in close proximity, and where the cow population is dense. In territories where the dairy industry is as yet in its infancy, where dairying is merely a side issue of beef-, grain-, or fruit-farming, where the herds are small and far apart, and where the cow population is sparse, the creamery cannot secure enough raw material to operate on a profitable basis by this system of securing cream alone.

An extensive survey on cost of milk and cream routes operated in the State of Maine, by Dow,[1, 2] showed that the dairyman's choice of creamery was influenced by the prices paid for

milk or cream, by board of health requirements, and by the cost of collection. About 27% of the dairymen did not deliver to their nearest receiving plant.

THE CREAM ROUTE SYSTEM

Advantages of Cream Routes.—The cream route system is the natural outcome of centralization of cream delivery. In this system the creamery establishes routes, and the hauling of cream is done by cream haulers engaged by the creamery. The hauler collects the cream at the farmer's door. One man—the cream hauler—with one truck and covering the distance in one circuit, thus is capable of bringing to the creamery the cream from a multitude of farmers, which by the door delivery system would require the time of scores of patrons, using as many conveyances and traveling many hundreds of miles in the aggregate. The route has possibilities of covering a much wider area and of bringing the market so close to the patron's door, that even the farmer who milks very few cows and produces a small amount of cream only, may patronize the creamery. The cream route, therefore, is a stimulant to the dairy business, it encourages the milking of cows, it saves the farmer valuable time and equipment necessary to haul his own cream, and it expands the cream supply territory of the creamery.

The length of cream routes naturally varies with density of cow population, keenness of competition, and many other factors. The average route probably covers a radius of about 50 miles, but it is not unusual for routes to extend as far as 100 miles or more.

Types of Cream Routes.—Some routes are operated on the so-called "bucket" plan. Here the hauler samples and weighs the cream of each patron on his truck, pours the cream into 10 gallon cans and delivers the weighed cream and the samples to the creamery. The objections of this system from the sanitary and quality standpoint are obvious. Experience with this system has further demonstrated that fat shortages are almost unavoidable.

Most of the routes in operation haul the cream in the farmer's individual cans and the sampling, weighing and grading is done at the creamery, thus eliminating the unavoidable insanitary features of sampling and pouring the cream enroute

and the inaccuracies of samples and weights taken on the truck, that are responsible for fat shortages and that often cause heavy loss to the creamery. When the cream is hauled in the farmer's individual can the factor of fat loss is automatically eliminated.

The route equipment—the truck—is either owned by the creamery, or by the hauler. If owned by the creamery its operation and up-keep are taken care of by the creamery. Under average conditions the expense of operations and up-keep may be approximately two cents per pound of fat delivered and the route hauler receives from about three-quarters of one cent to one and one-quarter cents per pound of butter fat. If the hauler owns the truck he defrays the cost of operation and up-keep and his commission is approximately from two and one-half to three and one-half cents.

When starting a route, and until it has been developed to a sufficient volume to insure a fair income to the hauler, the creamery usually pays the hauler a "living wage," in addition to his commission. To the haulers on some routes the creamery pays a straight daily wage and no commission. The wage rate paid by different creameries and to different haulers by the same creamery may show wide variations. Haulers on creamery-owned and operated trucks generally average from two and one-half to five dollars per day. If the hauler provides his own truck he may receive from about four to six dollars per day.

Cost of Route Cream.—The cost of securing cream by the route system is variously estimated to amount to about three cents per pound of fat. The price paid to the farmer for route cream is, therefore, approximately three cents below the price paid for direct-delivered cream. On some routes the hauler takes merchandise, such as canned goods, newspapers, etc., back to the farms. The returns from this miscellaneous freight in some cases offset a considerable portion of the cream hauling cost.

An enterprising hauler, operating in a region with a considerable cow population, may be capable of developing and expanding his route territory beyond the number of routes that he can personally cover two or more times per week. In such case, he may sublet some of his routes to other haulers who are responsible to him and who receive their commission or daily wage from him.

Most haulers are not residents of the town in which the creamery that receives their cream is located. As a rule their homes are either at the end, or somewhere along the line of their routes. Not all haulers bring their cream direct to the creamery. Many routes do not terminate at, nor even come near the creamery, but have their circuit at a considerable distance from the creamery and the hauler arranges with the railway station agent located at the route terminal, or with any other public or private carrier, to ship the cream to the creamery by rail or otherwise at conclusion of the day's work of the hauler. In this system the net price received by the farmer is usually, though not always, the same as that for any route cream, i. e., the gross fat price less the cost of hauling, and the creamery bears the shipping cost to the butter factory. The survey made by Dow,[1, 2] of the cost of operating milk and cream routes in the State of Maine shows that:

1. The hauling distance had very little effect on the type of product sold—milk or cream—or on the frequency of delivery.

2. The annual cost of operating motor trucks was $925.00 per truck, or 4.8 cents per mile. Of this, 52% was for gasoline, oil, grease and tires; 39% for depreciation and repairs; and 9% for interest, insurance, taxes and garage costs.

3. The total cost of operating collecting routes averaged $1,225.00 per route per year. Of this cost 60.6% was for the use of motor trucks, 35.9% for the collector's (hauler's) labor, and 3.5% for extra man and horse labor used when traveling was difficult.

4. The average cost of collection (hauling) was 23 cents per hundredweight. Collectors received, for operating their routes, an average of 34 cents, or a net return of 11 cents per hundredweight.

5. Increased volume reduced the price for collection. This was true of both increased volume per mile and increased volume due to increase in length of route in order to take on new producers.

6. Increased volume per mile caused the cost of collection to drop to as low as 8 cents per hundredweight. Collectors who traveled 120 miles per trip were able to reduce their cost per hundredweight about 22 cents below that on routes that were only 20 miles in length.

Qualifications of the Cream Hauler.—The cream route eliminates personal contact between patron and creamery operator at the time of cream delivery. The creamery contacts the patron through the person of the cream hauler. He is the go-between, or the creamery's ambassador to the patron. The cream hauler is its cream solicitor, its arbiter with, and its educator of, the patron. His accomplishments as a volume getter, his success of providing the creamery with quality cream, and of establishing and maintaining the patron's confidence in the creamery, are limited largely only by his qualifications of salesmanship, honesty, industry, knowledge and loyalty to the creamery.

Experience in the operation of the cream route system has amply demonstrated that the route that is most successful in building up a satisfactory and dependable volume of cream of good quality, and in accomplishing low cost of up-keep of equipment, is practically invariably the route that is manned by an efficient cream hauler of high character. On the other hand, the route that fails to develop a reasonably dependable volume, the route whose patrons lack permanency, the route the cream of which is persistently of poor quality, the route that shows an excessively high cost of equipment up-keep or that suffers an abnormal occurrence of avoidable accidents, is usually one whose hauler has neither the ability, the knowledge, nor the inclination necessary for the efficient performance of his duties as a cream hauler and as the creamery's representative for dealing with the farmer.

It is, therefore, of great importance, when establishing cream routes, for the creamery management to exercise diligence and judgment in the selection of its cream haulers, and to investigate painstakingly and consider seriously the character. the background, the experience, the outlook upon life, and the general all around fitness of prospective candidates for these important duties.

THE CREAM STATION SYSTEM

Development.—In the days of the whole milk creamery and the use of the centrifugal factory separator, many creameries, in efforts to expand their milk supply territory beyond a radius practicable for hauling the milk from farm to creamery, estab-

lished skimming stations suitably located to reach the milk supply from a large area. The farmers brought their milk to these skimming stations, where it was tested and skimmed, and from where the cream was hauled or shipped to the central creamery, and the skimmilk was taken back by the farmer for stock feeding purposes.

The subsequent introduction and use on the farm of the centrifugal hand separator, shifted the skimming of the milk back to the farm, so that the farmer again had cream to sell. In order to bring the market for cream closer to the farmer's door, and to draw their cream supply from a wider area, creameries established cream buying stations to which the farmers delivered their cream and from which each day's receipts were hauled or shipped to the butter factory. The skimming station thus gave way to the cream station. The cream station system developed with great rapidity and today, tens of thousands of cream stations are in operation, particularly in the central, north and south west sections of this continent.

Establishing and Operating Cream Stations.—In most states the location of the cream station must be approved by the State authorities before an operating license is granted. The cream station either belongs to the creamery or to the station operator.

In either case the creamery generally furnishes the necessary equipment, such as cream cans, cream scales, Babcock tester with glass ware and cream balance, can washer and steamer, and means to supply hot water or steam, cream sampling and grading instruments, and facilities to keep the cream cool until transported to the creamery. The cost of equipping a cream station is estimated at approximately $200.00. The creamery also provides the needed supplies, such as sulphuric acid, washing powder, and fuel, for operating the cream station.

The Creamery-Owned Station is usually designated a Service Branch. Its operator is the creamery's employee or agent. He solicits farmers' cream, services the patrons, and pays them either in cash or by creamery company check for the cream received. The price paid for the fat is dictated by the creamery; it is usually in line with the net cream route price or slightly below. In the case of shortages between creamery and station pounds of fat, the creamery absorbs the loss. The operator

usually receives a weekly wage for his service, the wage rate ranging from less than $20.00 to as high as $40.00 per week. In isolated cases his compensation may be on a commission basis. The commission usually paid by the creamery ranges from about two to three and one-half cents. The total cost of station operation necessarily varies considerably with such factors as locality, type of operator, volume of cream received, general economic conditions, etc.

The Operator-Owned Station is usually known as a Buying Branch. In most instances this type of cream station constitutes a sideline of an already established local business, such as a general merchandise store, grocery store, meat market, feed store, produce store, hardware store, shoe store, furniture store, filling station, etc.

In the case of the buying branch type of cream station, the owner or his helper operates the station. The creamery pays him a commission, generally amounting to from about two and one-half to three and one-quarter cents per pound of fat delivered. The operator pays the farmers out of his own account, either in cash, credit on merchandise sold by the store, or by check. The creamery reemburses the operator on the basis of the price of fat previously agreed upon plus the operator's commission. In case of fat shortages the operator absorbs the loss. The creamery buys this cream on the basis of the creamery's weights and tests.

Quality of Cream from Cream Buying Stations.—The status of the cream station is strategically favorable to supplying the creamery with cream of good quality. It receives its cream direct from each individual patron. It has the golden opportunity of personal contact with the patron at the time of each delivery. In case of defective cream the patron can inspect the cream and examine the sediment disc in the presence of the operator. The operator is in a position to furnish indisputable proof of the justification of paying less for poor quality cream. In case of an age limit grading plan, such as the four-day plan, fraudulent abuse is practically eliminated. The danger of misunderstanding and possible loss of the patron, that so often results from complaints sent to the patron by mail, is reduced to the minimum.

For above reasons, station cream might reasonably be

expected to be cream of good average quality. Unfortunately for the industry, experience fails to substantiate these expectations as related to the great bulk of station cream. The general run of cream station cream that reaches the creamery is of undeniably mediocre to poor quality, although there are many encouraging exceptions to these dismal observations.

The interests of the average station operator often are too far removed from the fundamental problems of the creamery business to envision the true creamery picture. Not being intensely creamery-minded, he also is not sufficiently quality-conscious to take full advantage, by his own volition, of his opportunities of soliciting the farmers' interest and co-operation in improving the quality of their cream, of conscientiously grading their cream at the station, and of sending the different grades to the creamery in separate cans. The buying branch (operator-owned station), because of the diversified nature of its interests, is usually more delinquent in this respect than the service branch (creamery-owned station).

But the fault does by no means always lie with the station operator alone. In fact, he is often more sinned against than sinning. Unless he is fully supported, both by word and by deed, on the part of the creamery, his efforts in behalf of quality cream are discouragingly handicapped. The operator himself may be the victim of competitive strife in his own locality, that causes efforts at cream grading and quality paying to jeopardize the success of his station. Or the very creamery that receives his cream may, in its quest for much-needed volume, or for competitive reasons, discourage his wholehearted efforts to "stand pat" on insisting on the patrons' conformance with his quality requirements. Generally speaking, the efforts, exerted by the station operator in behalf of cream improvement, and the quality of cream he furnishes the creamery, usually reflect fairly accurately the creamery's own standard of quality.

The Independent Cream Buyer.—Another phase of the cream station system is the institution known as the independent cream buyer. As the name implies, this type of cream station is entirely independent of the creamery in every respect. The independent buyer owns, equips and supplies his own station at his own expense. He solicits and purchases the cream from the farmers or other sources at his own price. He receives,

weighs and tests the cream, services the farmers and pays them. Unless he has a verbal or written agreement with the creamery for the sale of his cream, he is under no specific obligation to sell the cream, and he will sell it to the creamery that will pay him the best price. The creamery that deals with him, simply buys his cream, usually at a stipulated price based on market quotations, it pays him for it, regardless of how he secures it, or what he paid for it.

The creamery buys the independent buyer's cream on the basis of its own weights and tests. So, as far as the creamery is concerned, there are no fat shortages, unless the independent buyer reports an unusually larger amount of fat delivered than that recorded and paid for by the creamery. In such case an adjustment satisfactory to both contracting parties may be made. In normal operation the independent buyer absorbs both shortages and overages. The cost to the creamery of independent buyer cream usually averages about the same as the cost of cream from buying branches.

In the early days of independent buyer history, this type of cream station was not looked upon as a stable factor in the creamery business. The independent buyer's tendencies appeared to be nomadic; his cream supply of a floating nature, and his plans failed to contemplate permanency of business.

Today the independent buyer constitutes a recognized and generally dependable source of cream supply. Isolated exceptions reserved, however, independent buyer cream is of mediocre quality. As long as the independent buyer can find a ready and profitable market for the quality of cream he supplies, he sees no compelling incentive to grade and pay for the farmers' cream on the basis of quality, nor to keep different grades in separate cans. The cream he offers the creamery, therefore, is usually a mixture of good and poor quality, all one grade, and this "mine-run" cream is seldom of sufficiently good quality to make a full 90 score butter.

The Farmers' Co-operative Marketing Association.—Still another phase of the cream station system is represented by the farmers' cooperative marketing association. This is a cream producers association. Its members, the farmers, pool their cream and sell it through the medium of the secretary or other representative officer of their association.

These association cream stations have been in operation in various parts of this country for some time, and in some sections they constitute an important source of cream supply to the creamery. From a more or less loosely organized institution during the formative period of their early history, with a floating supply that was "shopped around" and sold to the highest bidder, they have emerged into well organized, stable associations with a dependable, permanent cream supply, selling their cream under yearly contract and on a graded basis.

In order to justify participation in a producers' association, the members inevitably must be in the business of producing at least a reasonable volume of cream. The producers supplying the association station, therefore, generally are dairymen, rather than one- and two-cow general farmers. In addition, their cream is received and paid for on a graded basis. Consequently, the general run of Farmers' Cooperative Association cream usually is of better average quality than the cream from other branches of the cream station system.

The equipment of the Association station is purchased and owned by the farmers, and the association bears the expense of operation. The cream receipts from the individual farmers are graded, weighed and tested, and the pooled cream is sold to the contracting creamery. The returns, after deducting operating expense and overhead, are prorated to the patrons on the basis of pounds of fat delivered by each producer. The creamery buys and pays for this cream on the basis of its own weights and tests. Fat shortages or overages, if any, are absorbed by the association.

THE DIRECT SHIPPER SYSTEM

Advantages of Direct Shipper System.—In this system the patron ships his cream to the creamery direct. Similarly as is the case with the door delivery system, the direct shipper system eliminates the middleman. But unlike the door delivery system, the direct shipper system has the advantage of an almost unlimited supply territory, enabling the creamery to draw its raw material from a much wider area. In this respect its possibilities resemble those of the cream route and the cream station systems.

Handicaps of Direct Shipper System.—Its outstanding drawback is that it does not provide personal contact between

patron and creamery or its agent, at the time of cream delivery. Aside from the possibility of the fieldmen's visits to the farms, and occasional dairymen's gatherings in which the creamery's representatives meet with the farmers, the direct shipper patrons are contacted largely by mail only. However, with a well organized, properly directed and aggressively active correspondence service, there need be no lack of efficient and satisfactory contact by mail, as is convincingly demonstrated by the recognized success of some of the foremost creamery organizations that operate the direct shipper system.

Effect of Shift of Carriers and Change of Economic Conditions.—The beginning of the direct shipper system dates back to the early days of the centrifugal hand separator. It came into being before the advent of the auto truck, and when all the direct shipper cream reached the creamery by rail. The passing of interurban rail transportation and the increasing elimination of local train service, have dealt the direct shipper system a severe blow in many sections of the country. While much direct shipper cream is still transported by rail and, while truck and bus service is available and used for direct shipper cream, this shift in available means of transportation, together with the almost universal distribution of farmer owned automobiles, and the general trend of competitive cream buying, have combined to favor other systems of cream buying somewhat at the expense of the direct shipper system.

Direct Shipper System Depends on Large Producers.—From the very beginning it was recognized that for economic reasons, the direct shipper system must cater to the larger producers. Past and present shipping rate regulations ignore the factor of volume of cream in the shipping can. Each size of can has its assigned shipping rate, regardless of whether the can is full or only part full. Economy of transportation therefore compels the shipping of full cans. This tends to automatically bar the one-to-three cow farmer from shipping direct. He would either have to suffer the higher cost of shipping his cream in cans only part full, or he would have to hold it so long in order to ship full cans, as to seriously jeopardize its quality. Nor has the small shipper responded to efforts on the part of the creamery, to ship in suitable cans of less than five gallon capacity. The changes that have transpired in the gen-

eral economic set-up of cream procurement, the shift in means of transportation, and the increasingly difficult competitive situation, have tended to divert the cream of the usual large direct shipper to other channels.

Quality of Direct Shipper Cream.—Formerly, direct shipper cream was of outstandingly better average quality than cream received from most of the other systems of procurement. Then, the average direct shipper produced a sufficient volume of cream to be interested in, and to have the natural inclination for providing facilities and efforts for proper care in its production and handling, and he was in a position to ship a full can once or twice per week, or oftener.

The diversion of the larger producer away from the direct shipper system has had the unmistakable effect of lowering the average quality of direct shipper cream. The individual shipments are of smaller average volume, there are fewer full cans and a larger number of part full cans, and there has been a tendency to prolong the interval between shipments.

The changing conditions indicated above, have diminished the permanency of the direct shipper. The turnover of direct shipper cream arriving by rail today is unduly large. The cream truck, on the other hand, has had an encouragingly stablizing effect on truck-transported direct shipper cream.

Elimination of Middleman Brings the Cream Direct to the Creamery. — In addition to the possibilities afforded by the direct-shipper system to vastly extend the creamery's supply territory, this system has the advantage of bringing its cream direct to the central creamery which usually has better facilities and talent for cream grading, sampling, weighing and testing and for the washing of the empty cans, than obtains at the great majority of cream stations. Furthermore, the cream, after it leaves the farmer's can, passes through the process of manufacture immediately, eliminating the possibility of deterioration due to unfavorable conditions incident to handling, prolonged holding and reshipping, such as often happens in connection with the cream station system.

While the direct shipper system does not lend itself readily to an age-limit system of grading, such as the four-day plan, the personnel of the central creamery is usually well trained and qualified to accurately grade by the senses of taste and

smell, as well as by the use of diverse physical and chemical quality tests.

Cost of Direct Shipper Cream to Creamery.—Because the direct shipper system eliminates the middleman, there are no fat shortages to absorb or to adjust. The transportation cost of direct shipper cream is charged to the shipper. The price quoted by the creamery to the patron is either the net price paid the farmer, or the gross price from which the shipping cost is deducted at the time of payment. The gross price is usually the same as that offered for door delivery cream and the net price to the farmers obviously varies with distance from creamery. Direct shipper cream usually nets the farmer from one to several cents over cream station cream.

Concentration Points.—Creameries procuring cream by the direct shipper system may establish and operate so-called concentration points. In such case the farmers ship their cream to the concentration point.

The concentration point usually is a plant equipped and manned by the creamery for receiving, grading, weighing, sampling, testing and cooling of the cream, for the washing, sterilizing and returning of the farmers' cans, for soliciting cream and for sending out the farmers' checks. The operator of the concentration point is an employee of the creamery.

The concentration point generally pays direct shipper prices. The cost of operation is borne by the creamery. Its inevitable drawbacks are: high-price fat to the creamery due to the added cost of operation of concentration points, losses in case of fat shortages which must be absorbed by the creamery, and jeopardy to the quality of the cream resulting from rehandling and reshipping and from delay of manufacture.

The operation of concentration points has for its purpose the further extension of the cream supply territory. Experience has demonstrated that it represents the most expensive system of cream procurement.

MANAGEMENT OF THE PATRON

The management of the patron in its fullest sense involves the successful solution of the following important problems:

1. The creamery must satisfy the patron with the price he is offered for his butter fat, in order to successfully solicit his

business. In the long run, the policy which will produce the most satisfactory results is that of consistently paying the highest price in harmony with existing market conditions and maximum efficiency of operation.

2. The creamery must secure the patron's confidence in its honesty and integrity, in order to maintain his patronage. This can only be accomplished by honest and accurate weights and tests, and it is greatly facilitated by giving the patron the benefit of the doubt in case of controversies where there is no indication of intentional dishonesty on the part of the patron.

3. The creamery must interest him in, and enthuse him over, his business, in order to induce him to produce more and to improve quality.

4. The creamery must educate the patron in larger, more economical and more profitable production. It should teach him to produce more pounds of butter fat per cow at less cost per pound. It should emphasize such care in production as to insure top returns for the cream. The average patron is appreciative of such information. Even if it is not new to him, he needs confirmation of his knowledge, in order to put it in practice with confidence and with maximum success.

5. The fundamental lesson on better care of cream must include cream grading and quality paying by the factory. In the absence of paying for cream on the basis of quality, attempts at accomplishing permanent cream improvement on the farm are futile.

REFERENCES

1. Dow, G. F., Me. Agr. Expt. Sta. Bul. 373, (1934).
2. Dow, G. F., Me. Agr. Expt. Sta. Bul. 374, (1934).

PART III

Butter Manufacture

CHAPTER IX

RECEIVING, GRADING, SAMPLING, AND WEIGHING MILK AND CREAM

When the milk or cream is received by the creamery or cream station and before it enters the manufacturing process, it is graded, sampled, weighed and "dumped" and the cans are washed, rinsed, steamed and dried, and re-tagged preparatory to returning to the patrons.

GRADING MILK AND CREAM

Purpose.—The grading of the daily receipts of milk and cream at the factory has a two-fold purpose, namely:

1. Each can of raw material is or should be graded for the purpose of enabling the creamery to pay for it on the basis of its quality, and to reject deliveries that are unfit for butter manufacture.

2. Grading is essential also in order to enable the operator to group the cream according to quality into such grades for manufacture, as will best suit the market requirements for different grades of butter.

Importance of Grading.—The manufacture of butter of superior quality depends, primarily, on good milk or cream. The quality of the raw material is the foundation of the quality of the finished product. The only permanently successful means for the creamery to insure a supply of milk and cream of good quality, is that of grading every can of raw material received and of paying for it according to its quality. This will make the market for a product of good quality attractive and profitable to the producer, and it will make his market for a product of inferior quality unattractive and unprofitable. There is no other dependable way to induce the average farmer to devote the effort and time in production and handling that is neces-

Fig. 32. A well arranged sanitary cream receiving floor

sary to insure quality. Grading and quality-paying, therefore, are of fundamental importance to the creamery in its efforts to establish a reputation for quality butter.

The quality of the raw material that arrives at the creamery reflects to a large extent the standard of ethics and of quality-consciousness of the creamery itself. Generally speaking, and exceptions reserved, the creamery will attract and receive the approximate grade of raw material that its conception, its ideals and its efforts on quality, stand for or tolerate.

Results of Grading in Butter-Exporting Countries.—The force of these facts is recognized by every thinking creamery operator. The realization of their importance by the industry has prompted countries that must depend for the returns from their butter on the exacting quality demands of the World market, to enact legislation for compulsory cream grading and quality paying. Thus, in New Zealand, Australia and the Western provinces of Canada, cream grading and quality paying are established facts that have resulted in constructive and permanent cream improvement. This in turn has enabled these countries to establish an enviable reputation for a uniformly high quality of their butter on the World market.

Cream Grading in the United States.—In the United States the progress made in the adoption of systematic cream grading and in quality improvement varies greatly with different regions of the country. In regions with a dense cow population and where the farmer derives at least 40 per cent or more of his living costs from dairying, such as is the case in large portions of the states of Iowa, Minnesota, Wisconsin, the Pacific Coast states and in limited sections of the South (particularly Tennessee and Mississippi), cream grading, and to a considerable extent quality paying, are an integral phase of creamery operation. The general quality of cream received is good and much of the butter produced is of high quality.

In the vast areas of the middle west, south and northwest, the quality situation is less favorable and progress in cream improvement has been less rapid. In large portions of these regions the cow population is relatively sparse. The farmer is not a dairyman. He depends for his livelihood largely on general farming, wheat growing, corn and hog raising, or cotton growing. He milks only a few cows and his returns from the product of the dairy cow are a secondary and usually a minor part of his farm income. The climatic changes are more extreme and there is often a lack of cool water in summer when most needed. In certain sections the pastures are infested by obnoxious weeds, such as garlic, wild onion, peppergrass, Frenchweed and the like, that impregnate the cream with these objectionable weed flavors. His distance from the creamery is often far, necessitating long hauls which are frequently accompanied by exposure of the cream in transit to unfavorable temperature conditions; and the small volume of product from his few cows limits the frequency of delivery.

This combination of conditions places the cream producer in large areas of the middle west, south west and north west at a disadvantage that is difficult to completely overcome or eliminate. The poor-cream situation in the Great Middle West has been further aggravated by a character of competitive strife among creameries bidding for this raw material, that has hindered progress in cream improvement. Nevertheless, the solution of the poor-cream problem in these sections is entirely possible, in spite of this multitude of obstinate difficulties. Constructive and permanent progress, however, demands an honest spirit of co-operation between all available agencies that

are interested in the industry; co-operation between the competing creameries themselves in adopting a workable standard for grades of cream and for price differentials between grades, and the will and unflinching determination of all components of the industry to stand by and enforce the standards agreed upon; active co-operation and good faith also between the producer, the manufacturer, the educational forces and the law-making and law-enforcing agencies.

Progress in Cream Improvement.—Within recent years there has been a country-wide awakening of the desperate need of cream improvement. This has resulted in the formulation and enactment of cream grading laws in the majority of the middle western states, in the organization of state cream improvement associations, in periodic inspection of cream at the creameries by State and Federal inspectors, in creamerymen's meetings for the purpose of mutual adoption of plans of operation, in educational campaigns on the part of dairy colleges and cream improvement associations disseminating practical information among the cream producers on the fundamentals of proper care of cream on the farm, and in devising simpler, more fool-proof and more equitable methods for grading at the cream station and in the creamery. These efforts have produced gratifying results in those localities where they had the sincere and courageous support of the industry. They have failed, however, in other sections where the industry's co-operation was limited to "lip-service" and meaningless noise. Laws, regulations and agreements are no stronger than the will of the industry for whose benefit they are made to have them enforced.

CLASSIFICATION OF CREAM GRADES

The purpose of establishing cream grade standards is, or should be, to unify the activities of the industry in its efforts to improve the quality and wholesomeness of its cream supply. In the interests of efforts towards the accomplishment of a National Brand of American butter of high quality, a national classification of cream grades appears inevitable. For a country of such expanse and of such a wide range of geographic, climatic and economic conditions, as obtains in the United States, a national classification of cream grades must provide a flexibility and a range of grades that gives consideration to the require-

ments of the industry in every section of the country. It must be applicable to the sections of intensified dairying that are capable of producing a raw material of high average quality, and it must satisfy the conditions of those other sections where dairying is a secondary sideline of farming only, and where the geographic, climatic and economic status is less favorable to the production and delivery of cream of high quality. It is with these purposes and aims as the goal, that the following classification of cream grades has been assembled and is recommended:

Special or Sweet Cream Grade.—Cream that is clean, fresh, sweet and free from any off-flavor, free from any visible or objectionable extraneous matter; and the acidity of which has at no time exceeded two-tenths of one per cent, calculated as lactic acid.

First Grade Cream.—Cream that is clean in flavor, free from off-flavors and from objectionable extraneous matter; and the acidity of which has at no time exceeded six-tenths of one per cent, calculated as lactic acid.

Second Grade Cream.—Cream may have an acidity in excess of six-tenths of one per cent. It may contain objectionable flavors and odors to a moderate degree, such as slightly cheesy, slightly rancid, slightly tallowy, slightly metallic, slighty bitter, slightly yeasty, etc. It must be free from the flavor and odor of obnoxious weeds, such as onion, garlic, leek, Frenchweed, peppergrass, etc.; from the flavor or odor of gasoline, kerosene, machine oil, or other foreign oil; from contamination with dirt, filth and other objectionable extraneous matter; and from mold and products of putrefaction.

Weed Flavored Cream Grade.—To this grade belongs all cream suitable to be classed with any of the previous grades, but that is infested with the flavor of obnoxious weeds, such as onion, garlic, leek, Frenchweed, certain weeds associated with peppergrass, etc.

Illegal Cream.—This includes all cream that fails to meet the requirements of any of the previous grades. It is cream that contains the flavor of gasoline, kerosene, machine oil, or other foreign oil; or that is so deteriorated as to have a pronounced cheesy, rancid or metallic flavor; or that is contaminated with

products of putrefaction, or dirt, or filth or other objectionable foreign matter that renders it unfit for human consumption.

Practicability of the above Classification of Cream Grades and Their Relation to the Market Scores of Butter.—The cream grades listed above are intended to provide a sufficient quality range to be applicable and equitable to practically every section of the country, where butter is manufactured commercially.

The Special or Sweet Cream Grade refers to cream of the finest quality, fresh, clean, sweet, large volumes of which are produced in the sections of more highly specialized dairying, where the cream producer derives a large portion of his farm income from dairying. This grade of cream makes butter of a quality that scores 92 points or better.

The First Grade represents the great bulk of No. 1 cream received by the quality-conscious creameries of the corn belt states of the middle west. It is of a quality that yields butter scoring 90 to 91 points, a good commercial butter that lacks the finer flavor of butter made from Special Grade, but is of sufficiently good quality to satisfy the great masses of the butter eating consumers.

While the acid limit of six-tenths of one per cent permitted in "First Grade Cream" is in itself not necessarily objectionable or damaging to the flavor of the butter, yet it is too high for butter manufacture without the use of an amount of neutralizer that robs the product of the fine flavor of Sweet Cream Butter.

The acid limit is conservatively set at six-tenths of one per cent, because for cream of average richness (containing 30 to 40% fat) six-tenths of one per cent cream acidity is equivalent to a serum acidity of approximately .85 to 1.00%. At this acidity the lactic acid bacteria have reached or passed the peak of their activity, and beyond this acid limit they begin to surrender their predominance to other species, usually those that encourage decomposition changes damaging to the flavor of cream and butter. Under normal and usual conditions of temperature and age, cream in which the acidity has not yet exceeded the six-tenths per cent, is still sufficiently free from the type of fermentations that cause objectionable off-flavors, its flavor is still good enough to make a good 90 score butter.

However, the acid limit is no guarantee of freedom from fermentations of more objectionable nature. The quality of

such cream depends in addition on the sanitary standard of its production, temperature, and age. Brown[1] who conducted experiments for the purpose of determining whether cream that has soured to an acidity of .5 to .6% before neutralization, could still be made into first grade butter (butter scoring 38 points on flavor on the basis of the Canadian standard of butter scoring), concluded that the kind of cream used in his experiments (acidity .5 to .6%) cannot be depended upon to make first grade butter.

Second Grade Cream is distinctly a poor quality product. Excepting weedy cream, it is the lowest grade that should be and need be considered for butter manufacture. Its low quality is due to fermentation flavors. It yields a quality of butter that scores 88 to 89 points on the market.

The Weedy Cream Grade fills a real need in the picture of cream grade standards. Such cream is an economic menace to the creamery, because of the severe condemnation on the part of the trade, of butter harboring these obnoxious flavors. The flavors of such weeds as onion, garlic, leek, Frenchweed and of certain weeds associated with peppergrass disqualify such cream from all previous grades. Butter made from this weedy cream is penalized severely on the market. Regardless of the quality of the cream otherwise, whether Special Grade, First Grade or Second Grade, butter impregnated with these weedy flavors, even to a slight extent only, usually receives a market score of 87 or lower. Weedy cream, while often of good quality from the standpoint of freshness, should be paid for on the basis of the low market value of the butter which it produces.

Illegal Cream should include not only all cream that is unfit for human consumption because of contamination with mold, dirt, filth, products of putrefaction, kerosene, gasoline, machine oil or other objectionable extraneous matter, but it should embrace also all cream that has been allowed to ferment to the point of showing a pronounced cheesy, or rancid or metallic flavor. Cream sufficiently stale to contain these and similar fermentation flavors to a pronounced degree, will no longer make 88 point butter. Such cream is unfit for butter manufacture and should be condemned. Its acceptance and use nullifies efforts at cream improvement. It is a hindrance to progress and a costly liability to the butter industry.

METHODS OF CREAM GRADING

The several factors on the basis of which the quality of cream may be estimated or determined, and which lend themselves to practical factory tests are: flavor, odor, and appearance to the eye, acidity, extraneous matter and age limit. Chemical tests, such as the indol test and the formol test, that show the extent of protein decomposition which the cream may have suffered, are too complicated for the limited time, technical talent and available facilities in the cream station or creamery, to justify consideration for use on the cream grading floor.

Grading Cream for Flavor, Odor and Appearance.—The senses of the cream grader are the most practical and generally the most dependable judges of quality. The most important attribute that determines the quality of the cream is its flavor. The only dependable way of testing the cream for flavor is by tasting it. No special expert knowledge is required to distinguish good cream from bad cream. Any individual with average sense of taste can do that. If every cream buyer did no more than that, but did that conscientiously and paid for the cream according to the quality determined in such manner, the industry would be well on the road to marked cream improvement.

The recognition of specific off-flavors present only to a slight degree, such as slightly metallic, slight peppergrass, slight onion, etc., is somewhat more difficult; it requires a keen sense of taste and considerable practice. Such talent is particularly valuable in grading for butter manufacture. It assists the buttermaker in culling out cans that are only slightly tainted with these highly objectionable off-flavors, from churnings intended for first grade butter, thereby protecting the creamery from the danger of heavy penalties when marketing its butter.

Operation of Grading by the Senses.—The odor in the can and the appearance of the cream to the eye usually convey a general idea of the character of the cream and what its flavor may be expected to be. It is helpful, therefore, to examine the cream for odor and appearance as soon as the can is opened and before it is stirred, preparatory to tasting it.

When smelling of the cream due cognizance should be taken of the fullness of the can. Cans only partly full are prone to show more intense odors than full cans, because of the air and

gases that collect above the cream. A strongly cheesy, rancid or putrid odor in any can, however, suggests hopeless deterioration that places such cream in the Illegal Grade.

The appearance of the cream furnishes an additional index to its quality and its grade. Cream of good quality has a smooth body, free from lumps of curd and wheyed-off liquid, it is free from visible extraneous matter and shows no mold. If it is curdy, wheyed-off, dirty, or moldy on the surface, there can be no question that it is of such inferior quality as to be unfit for acceptance.

Technique of Grading Cream by Taste.—Being a food product, the grading of cream should be performed in an approved manner from the standpoint of ethics and sanitation. This can

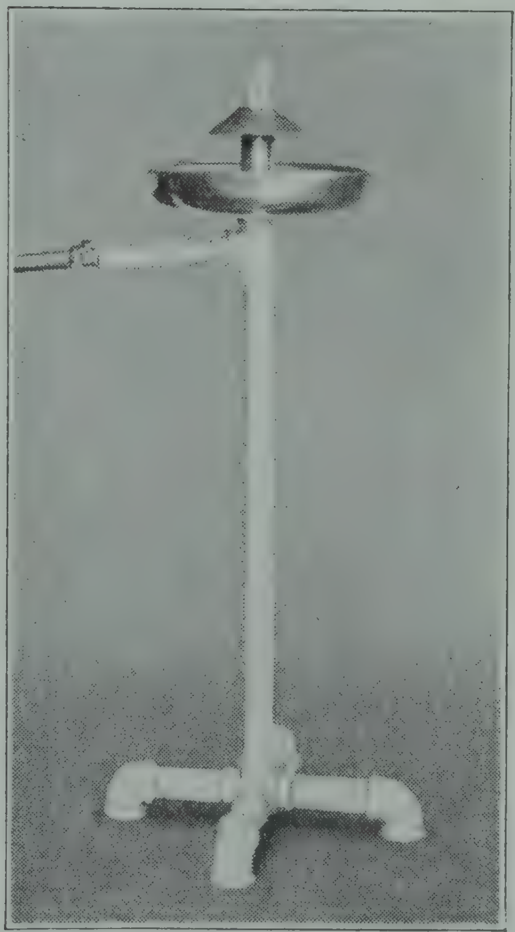


Fig. 33. Dental spittoon for cream grading

Fig. 34. Cream stirrer with slide

be readily done without interfering with satisfactory efficiency of operation, by providing suitable apparatus as follows:

1. Cream stirrer with perforated, six-inch diameter disc at its lower end. The stirrer should be equipped with a slide

with suitable handle for removing the remnants of cream from the rod of the stirrer.

2. Glass rods, or Bakelite rods, diameter three-eighths inch, length six inches, rounded at both ends, or teaspoons.

3. Dental spittoon resting on a pipe standard, and equipped with a warm water cup and hot water connections. For convenient shifting of the spittoon to all parts of the grading floor the water connection is advantageously provided with rubber tubing of adequate length, and universal joint in the hot water supply pipe to which the rubber tubing is attached.

In the absence of the dental spittoon any sanitary cup for hot water in which to rinse the grading rods may be used, and a box on the floor containing absorbent material, such as saw dust, is suitable for the necessary and unavoidable expectorations.

Operation of Grading by Taste.—Stir the cream in the can vigorously with the cream stirring rod. When removing stirrer for transfer to next can, pass the slide from top to bottom of the stirring rod. This scrapes off the cream, permits it to run back into the can, and thus prevents spilling and unsightly slobbering.

Have at least two grading rods in the warm water cup of the dental spittoon and turn on the water so the cup overflows continuously. Remove one of the glass rods, dip it into the cream of the first can, lick it off for tasting, and return it to the warm water cup for rinsing. Expectorate the cream tasted, into the bowl of the spittoon where it is carried down to the floor through the standpipe by the warm water that overflows from the cup in which the glass rods are being rinsed.

This method is rapid, efficient, sanitary, and ethical.

Grading Cream on Basis of its Acidity.—Sweetness and sourness are relative terms. If sourness referred to every degree of acidity, then all cream would be sour, for all naturally produced cream contains some acid. The grader's sense of taste tells him whether cream is sweet or sour to taste, and in the case of sour cream, whether the cream is moderately sour or high in acidity.

When the grade standard limits the grade to a definite maximum per cent acid, such as two-tenths of one per cent for Sweet Cream Grade and six-tenths of one per cent acid for First

Grade, the sense of taste is seldom keen enough to accurately determine to which grade certain cans of cream belong, on the basis of their acid content. This is especially true in the case of "border-line" cream. Such cream, therefore should be tested by means of a chemical acid test. For this purpose the standard acid test equipment may be used. However, in order to expedite the operation and to avoid delay in the routine of grading, it has been found advantageous to use a modified acid test that tells the operator instantly whether any given can of cream falls within the acid limit of the respective grade. For directions see "Rapid Acid Test" in Chapter XXV.

Grading Cream on the Basis of Extraneous Matter. The Sediment Test.—The presence in cream of extraneous matter of any kind is objectionable. Foreign material of sufficient coarseness to be visible to the eye, is automatically detected in the routine operation of grading. If present to any considerable extent, such cream classes as second grade. In the case of offensive material the cream is illegal and should be rejected.

Absence of visible extraneous matter, however, does not necessarily signify clean cream. The foreign material may be of such small particle size, or in semi-solution, to be hidden to the eye by the natural opacity of the cream, and yet it may be present in considerable amount. Its detection, however, is made possible by subjecting a sample of it to the sediment test for which directions are given under "Sediment Testing" in Chapter XXV.

As a basis for the grading of the daily cream receipts at the creamery or cream buying station, the sediment test is not practical. To make it effective would mean the sediment testing of each can of cream, and of doing this testing before the cream is "dumped." To be sure, this can be done, but it so retards the daily routine operation, lowers plant operating efficiency and increases cost of butter manufacture, that execution of this practice would inevitably doom it to failure.

It is desirable and feasible, however, to sediment-test each patron's cream at reasonable intervals, such as once per month. This provides the creamery with a general idea of the sanitary condition of its cream receipts, and enables it to caution the patrons whose cream yields unsatisfactory sediment discs. Most states whose cream grading rules make sediment testing com-

pulsory, require monthly sediment tests only, with the proviso that in the case of dirty sediment discs, each subsequent delivery of cream must be tested until satisfactory improvement is evident.

Aside from its merits as a means of grading out objectionably unclean cream in the factory, the outstanding merit of the sediment test lies in its educational value for cream improvement. The sediment disc constitutes tangible evidence, visible to the eye, and thus is an effective means to convince the producer of the relative purity of his cream. A dirty disc tends to arouse his curiosity as to the reason, and his pride to have his product compare more favorably with that of his neighbor. In order for these benefits to materialize, the creamery must bring the sediment disc to the attention of the patron, such as by posting the discs regularly on a board in a place in the factory readily accessible to the patron, or by mailing the discs to the patrons, together with suitable comments. For details see Chapter XXV.

Grading Cream on the Basis of Its Age.—The Four-Day Plan.—The quality-deteriorating influence of age on the cream was discussed in Chapter VI on "Care of Milk and Cream on the Farm." It was shown that age is the arch enemy of quality. A grading system that is based on the age of the cream, and that insists on paying for it according to a definite age limit, appears therefore sound in principle. It should tend in the direction of more frequent delivery and of discouraging the sale of objectionably old cream. It has the further advantage of supplementing the uncertain talent of grading by the sense of taste, with a positive and more fool-proof line of division between grades, such as is possible of operation on the part of any buyer regardless of his status of expert skill, judgment and experience.

One of the best known plans of grading cream on the basis of its age, that is in operation in many sections in the middle west, is the Four-Day Plan, conceived and developed by Professor H. W. Gregory, Chief of Dairy Department, Purdue University. In this system all cream, the age of which does not exceed four days, and that is otherwise free from objectionable flavors, is classed as Premium Grade and receives a price higher than the regular price paid for cream that does not conform to the Four-Day limit.

In this system the empty can that is returned to the producer is tagged by the creamery or buyer with a tag bearing the date of the previous delivery. This tag remains on the can until the next sale of cream, when it is detached and marked with the date of arrival. The tag thus shows the time interval between the present and the previous delivery. If this interval is four days or less, the cream goes into Premium grade and is paid for accordingly. If the interval between deliveries exceeds the four-day limit, the cream is classed as Regular grade and receives the price assigned to that grade.

In sections where the majority of the creameries have adopted the four-day plan and competitors are honestly conforming to its provisions, the Four-Day Plan has accomplished considerable cream improvement. It is especially adapted to the cream station system of buying cream. Its successful functioning requires intelligent supervision by properly qualified supervisors.

SAMPLING MILK AND CREAM

Importance.—The purpose of sampling the milk or cream received at the creamery is to determine the milk fat contained therein, on the basis of which the product is paid for. The first and fundamental requisite for accurate fat tests is that the sample be representative of the composition of the product received. In the absence of correct samples the accurate determination of the per cent fat of the raw material received is impossible. It is, therefore, of vital economic importance that the method used for sampling, and for the care of the sample, be such as to insure samples that are truly representative of the milk or cream received. The fat, being the lightest of the milk constituents, readily rises to the top. For correct sampling, therefore, there is need of thorough mixing immediately before the sample is taken. At the same time it is imperative for economic reasons, that the method of sampling be so designed as to provide a proper sample with a minimum expenditure of routine labor.

Sampling Milk.—In the absence of a weigh can, where the sample is taken from individual cans, the milk in each can may be properly mixed before sampling, either by pouring from one container to another or by thorough stirring. For milk that is in normal condition one pouring is usually sufficient.

Pouring at least twice, however, is recommended of cans in which the fat has risen to the top in the form of a compact layer of cream. Proper mixing by stirring requires the use of a suitable stirrer with rod sufficiently long to readily reach the bottom of the can. The stirring must be vigorous, running the stirrer from top to bottom several times.

Where the milk is "dumped" into an ordinary weigh can the mixing is not always sufficient to provide dependable homogeneity of composition in all parts of the weigh can, and either stirring the milk in the can before "dumping," or in the weigh can after "dumping," is necessary to insure representative samples. In recent years weigh cans are being equipped with a grating which breaks the milk up more completely and provides sufficiently uniform fat distribution for proper sampling without the necessity of resorting to additional, time-consuming stirring.

There are three principal ways of taking milk samples; namely, individual samples of each patron's milk that are taken and tested daily; or individual samples taken at intervals of two, three, four or more days, in which case the butter fat is computed by multiplying the total pounds of milk delivered by the average of the individual tests either weekly, bi-weekly or monthly; or daily samples are composited and tested weekly, bi-weekly or monthly; or individual samples taken at intervals of two, three, four or more days are composited and tested weekly, bi-weekly or monthly.

When taking individual samples, it is usually found most convenient to pipette the sample from the properly mixed milk in the patron's can or the weigh can direct into the Babcock milk test bottle, using a 17.6 cc pipette. In the case of composite samples aliquot portions of each day's delivery when samples are taken (either daily, or at intervals of several days) are transferred to properly numbered sample bottles with tight seals; one bottle being provided for each patron. This is readily done by the use of a "milk thief" or a graduated pipette. Fairly accurate composite samples may be taken also by using the same measure for all deliveries. A small dipper holding from one-half to one ounce generally proves serviceable. While not mathematically correct, this method of composite sampling yields results corresponding very closely with those of aliquot

portions of milk, because the daily deliveries of milk from the same patron seldom vary appreciably within the usual short period (about 7 to 14 days) which the composite sample represents.

In order to guard against fermentation changes that would interfere with the proper mechanical re-emulsification preparatory to testing, the composite sample should contain a suitable preservative, such as corrosive sublimate, or potassium bichromate. This is conveniently added in tablet form, placing one tablet into each jar at the beginning of the period during which the sample is to be held. During hot weather it is advisable to use two tablets. The composite samples should not be held too long, as excessive age makes final mixing difficult. It is preferable to test such samples at the end of each week. As each daily portion of milk is added it should be mixed with the remainder of the sample already in the jar by giving the jar a gentle rotary motion. The jars should be tightly sealed to guard against evaporation, and should preferably be held in the cold room when not needed on the receiving floor.

The taking and testing of individual samples at intervals of several days (3 to 5 days) yields fully as accurate results as composite sampling. As previously pointed out, the richness of milk from one and the same herd is generally quite uniform from day to day; and the immediate testing of the sample eliminates the danger of inaccuracies due to difficulties in securing truly representative portions for the test. This is always more or less in evidence with composite samples.

Sampling Cream.—A representative sample may be obtained from fresh, sweet cream, of moderate richness, in the same manner as used for the sampling of milk. Cream is more viscous than milk, however, requiring more stirring or pouring to insure a uniform mixture.

In the case of sour cream, correct sampling that yields representative samples is more difficult and requires more attention and effort. This is partly due to the greater richness and wide range of richness between different lots of cream received from the small producer, and partly to the physical condition of much of the sour cream received.

Average cream contains approximately ten times as much fat as milk. The possible error caused due to lack of uniformity

of composition, therefore, is greatly augmented. Furthermore, sour cream is usually several days' old, it may be very thick and sometimes lumpy, requiring extra vigorous stirring in order to accomplish a mixture of uniform composition.

Composite samples of cream, representing portions of successive shipments or deliveries from the same patron, intended to be tested weekly, bi-weekly or monthly, generally prove unsatisfactory. They may yield correct tests when taken with special care and kept in tightly sealed jars stored in the cold room. Under average creamery conditions, however, composite sampling of cream cannot be recommended. It is difficult to obtain small aliquot portions of cream that are truly representative. Furthermore, the general practice of keeping the sample jars on the shelves of the warm receiving platform invites evaporation of moisture accompanied by a corresponding increase in the per cent of fat. This in turn causes such samples to yield excessively high and misleading tests, as shown by Hunziker, Mills and Spitzer.[2] Finally, the established practice among many creameries of paying the farmer for each individual shipment of cream makes necessary the testing of each shipment and, therefore, precludes the practicability of taking and holding composite samples.

In all cases of sampling, whether such work be done at the creamery, at the cream station, or on the route, the greatest care should be taken that the cream is mixed very thoroughly before sampling. This requires a stirrer with a good sized disc and a stout rod not less than three feet long and with a hand hold of adequate size. The stirring must be done thoroughly, simply giving the cream a few dips with the sample dipper is not sufficient. The stirrer must be worked to the bottom of the can at least one-half dozen to a dozen times and the entire contents of the can must be thoroughly agitated. Thick, lumpy, or icy cream should be warmed until it pours readily and can be mixed properly. Churned cream cannot be sampled. Its fat content may be calculated by testing the buttermilk and estimating the amount of butter.

In order to guard against serious fat shortages and to protect the creamery against paying for more butter fat than it received, all cream arriving from cream stations, from independent buyers, from co-operative producers' associations, and from cream haulers who sample the individual patron's cream on the

route, should be sampled and tested at the creamery. This is readily done by making one or more composite samples from all the cream received from each individual station, independent buyer, or cream route.

For this purpose the use of a sampler that takes aliquot portions is advisable, such as the McKay cream sampler. Each can, after being well stirred, is sampled and the sample is transferred from the can to a jar or pail. When all the cans of one station, buyer, or route have been sampled, the cream in the pail is thoroughly mixed, and a sample is taken from this composite cream and tested. In order to avoid the danger of erroneous results, it is advisable to limit the number of cans used for the composite sample to ten. If the volume of cream from any one station, buyer, or route exceeds ten cans to a considerable extent, as for instance in the case of sixteen cans, it is preferable to make two composite samples, using eight cans for each.

Or, all cans from the same station, buyer or route may be "dumped" into a weigh can or vat, thoroughly mixed, and samples taken from the cream at several places in the vat. The former method, however, has been found by experience, to yield more nearly representative samples, because of the difficulty of adequately mixing a large body of cream consisting of different lots of varying richness.

Prompt testing of these composite samples and, in case of fat shortages, immediate notification of the buyer, will assist in avoiding similar shortages in future shipments.

Sampling Frozen Milk or Cream.—When milk or cream arrives at the creamery in partly or wholly frozen condition, it is practically impossible to secure from it a representative sample while in this condition. During the process of freezing, ice separates in the nearly pure state from the liquid, causing an increase in the concentration of the unfrozen portion. The product in the can usually freezes from the surface down and from the sides toward the center. However, since in the case of milk, the cream is usually in the surface layer, and in the case of cream, the richer cream is at the top, the frozen milk and cream in the top of the can is usually abnormally rich in fat. The fat concentration in the frozen and unfrozen portions is dependent, therefore, on the extent of creaming that has taken place prior to and during the progressive freezing, causing sam-

ples taken from such cans to be of uncertain composition and fat content.

If only slightly frozen, milk and thin cream may be thawed out by warming, and when in completely melted condition will yield representative samples upon proper stirring. Frozen cream of the usual wide range of richness received at the creamery requires special treatment to reduce it to a satisfactory liquid for sampling.

The usual practice of setting cans of frozen cream in hot water at a temperature ranging from about 110°F. to 130°F. and upward is objectionable because at these high temperatures a portion of the milk fat in the can melts and "oils off." This in turn renders accurate sampling almost impossible due to the inability of the melted separated fat to re-emulsify with the rest of the cream by hand stirring. Also, butter made from such cream tends to have a mealy texture.

These objections may be entirely eliminated by holding the temperature of the warm water in the cream-thawing tank below the melting point of the butter fat. This is best done by heating the water in the tank to 95°F. only. In order to hasten the melting of the cream, allow a stream of water at 95°F. to flow through the tank constantly. In this way the cream melts in a natural manner and without "oiling-off"; and the continuous removal of the cooled water surrounding the cans, by the circulation of the water, expedites the thawing. Cream so treated is in ideal condition for sampling and the danger of mealy texture in butter is eliminated.

Care of Milk and Cream Samples.—All sample jars both for milk and cream, and for individual as well as composite samples, should be tightly sealed immediately after sampling, to guard against evaporation of moisture and erroneously high tests.

Individual samples are best tested immediately, i.e., on the day on which they are taken. If held 24 hours or longer, they should be placed in the cooler. All composite samples that are held over 24 hours should be held in the cooler between sampling days. Where testing is done at intervals longer than one week, it is advisable to add two preservative tablets at the beginning of the sampling or holding period. For shorter holding periods, one tablet is sufficient.

The shorter the period of holding composite samples, the less the danger of increased test due to evaporation, and the better the physical condition for proper preparation of the contents for the test, and for correct results. It is advisable to use containers only large enough to hold the required amount of composite sample, and the samples are preferably held in the dark.

WEIGHING AND "DUMPING"

Weighing Milk.—The cans belonging to one and the same patron are usually emptied into the weigh can and the weight is recorded on the milk sheet located in a convenient place on the receiving platform. Where milk exclusively, or nearly so, is received, the patrons are generally paid weekly, bi-weekly, or monthly, and it is convenient to have the milk sheet provide for a sufficient number of days to enable the operator to enter all the daily receipts that constitute the period for which the pay check is made out.

Weighing Cream.—The above method may also be used for individual deliveries and shipments of cream, and the route and station totals may be entered in the columns reserved for the respective routes and stations.

In large creameries and where the individual cream receipts are paid for daily, the milk and cream sheet obviously does not serve the purpose. In those cases the cream is usually weighed in the cans before it is emptied. The tare weight indicated on the shoulder of the can and the gross weight are recorded on the tag of the can, or on a cream record blank, which later goes to the office. Station and route cream is usually weighed by placing all the cans of the same station or route on the scales or by pouring into the weigh tank.

In order to insure correct weights, the platform scales at the creamery and cream station, and the spring scales on the route wagon, must be in good operating condition. They should be regularly examined at the beginning of each day and tested by the use of standard check weights several times during the course of the day's work. Platform scales should be set level, be properly balanced, swing freely, and indicate the weight correctly. Scales that "stick" or that are otherwise not in satisfactory operating condition should not be used. The scales should be protected against undue jars and should be thoroughly

cleaned and freed from all remnants of milk and cream at the conclusion of each day's work. Bearings and knife edges should be inspected at regular intervals, and kept free from rust. Worn parts should be replaced by new ones. On the care of the scales will largely depend their accuracy and their duration of usefulness.

Dial scales are preferable to beam scales; they function automatically, record the weight quickly and clearly visible to the operator, as well as to the patron who may watch operations.

"Dumping" Milk.—As previously stated the milk cans are most conveniently emptied into the weigh can and after weighing, the milk passes into the receiving vat and is heated preparatory to separation in accordance with directions given in Chapter VII on the "Separation of Milk." All milk should be strained through a suitable strainer, preferably a wire mesh strainer, with about 125 meshes to the inch. This is best done by installing the strainer over the top of the weigh can. The strainer should be rinsed out frequently during the day's work, and at the end of the day it should receive a special scrubbing with brush and hot water, and should be steamed. The use of a drip rack for reclaiming remnants of milk in the cans will assist in avoiding unnecessary losses on the platform.

"Dumping" Cream.—Cream, after it is weighed, is usually emptied into the forewarmer which consists of a low vat equipped with a revolving coil for warming the cream. It is desirable to forewarm all cream so as to reduce it to a homogeneous condition and make pasteurization more even and more effective. In the forewarmer the cream is heated to about 90°F. If higher temperatures are used care should be taken that the cream is constantly agitated by keeping the coil revolving, in order to guard against "oiling-off" of the butter fat and consequently a mealy-bodied butter. In the case of sour cream, the forewarming temperature before neutralization should be limited to 90°F. in order to avoid heat-curdling that is conducive to excessive fat losses in the buttermilk. The forewarmer should be equipped with a coarse but substantial strainer.

Since much of the cream arrives at the creamery in very thick condition, special attention must be given the rinsing of the cans in order to prevent heavy loss of butter fat. After the

can is emptied it is best inverted over a steam jet with openings about one-eighth inch in diameter through which steam is blown into the can until all the cream has run out. It has

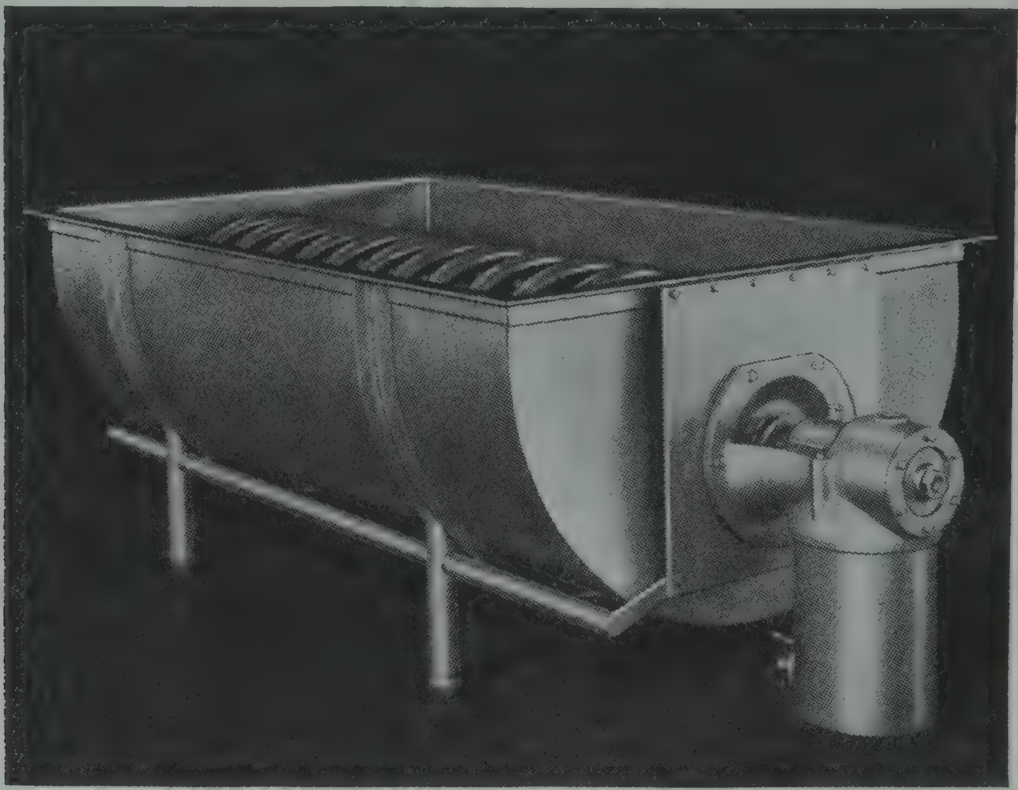


Fig. 35. "Dump" tank and forewarmer
Courtesy of Cherry-Burrell Corporation

been found convenient to arrange such steam jets for cans and can covers over the forewarmer permanently.

CAN WASHING

Importance.—One of the essential factors in the creamery's successful efforts to improve and uphold the quality of its supply of milk and cream constitutes the return to the farmer of cans that are clean, dry and sweet-smelling. It is inconsistent to urge the producer to observe scrupulous cleanliness and sanitation in the production and handling of his milk and cream, and then furnish him with cans that are not clean and that contain foul odors. Even milk or cream that is sweet and free from objectionable flavors and odors, when poured, stored and shipped in unclean cans, will be of inferior quality by the time it reaches the creamery or cream station. And the psychological effect on the producer who, upon opening the can, detects bad odors and lack of cleanliness, is disadvantageous to the cause of good milk or cream.

Nor does the influence of the condition of the returned empties stop with the effect it has on the quality of the cream.

The can is a mirror in which the patron sees the creamery. If the creamery's promise of service to the farmer means anything, it must express itself in the form of clean, sterile and dry cans, returned to him promptly. This type of tangible service impresses the patron and is a distinct asset that facilitates the creamery's efforts to hold his patronage. The proper cleaning of the cans at the factory, therefore, affects quality, volume and good will, and no creamery operator interested in the permanency of his business can afford to ignore or neglect it.

Essentials of Efficient Can Washing.—In the proper cleansing of cans there are four essential operations; namely, the washing, rinsing, steaming, and drying.

The washing of the cans should remove all remnants of milk and cream, after which they should be thoroughly rinsed so as to eliminate completely the washwater. The rinsing is preferably done with hot water in order to preserve the effectiveness of subsequent steaming. The cans are then ready for the steaming which should be continued until the cans are "piping hot." If possible, superheated steam should be used for this purpose. The steaming should last not less than 30 seconds and preferably longer. The steamed cans are then dried, either by inverting them open on a can rack, or by blowing dry heated air into them. After drying it is best to leave them open for at least 10 to 15 minutes to permit the escape of the heated air and thereby prevent condensation of moisture upon cooling, or the heated blast may be followed by a cool air blast.

Can Washing Equipment.—Where a mechanical can washing machine is not available, hand washing must be relied upon. In this case a wash tank of suitable size should be provided, where the cans may be washed, inside and out, in a hot solution containing washing powder, and be scrubbed with a stiff brush. For the rinsing and steaming, water and steam jets may conveniently extend through the drain board located at one end of the wash tank and be operated by valves with foot lever attachment. A dryer may be improvised by blowing air through a box filled with heated steam coils. In the absence of such a dryer the cans should be allowed to drain and dry by inverting them over a can rack in a clean place, preferably in the sun. The can cover should receive similar treatment as the can.

There are now on the market numerous makes and sizes

of can washing machines, adapted to the needs of every type and size of creamery. These machines eliminate a large part of the human factor in the usually distasteful work of can washing as done by hand. When operated right, they do far better work than the average individual usually does by hand.

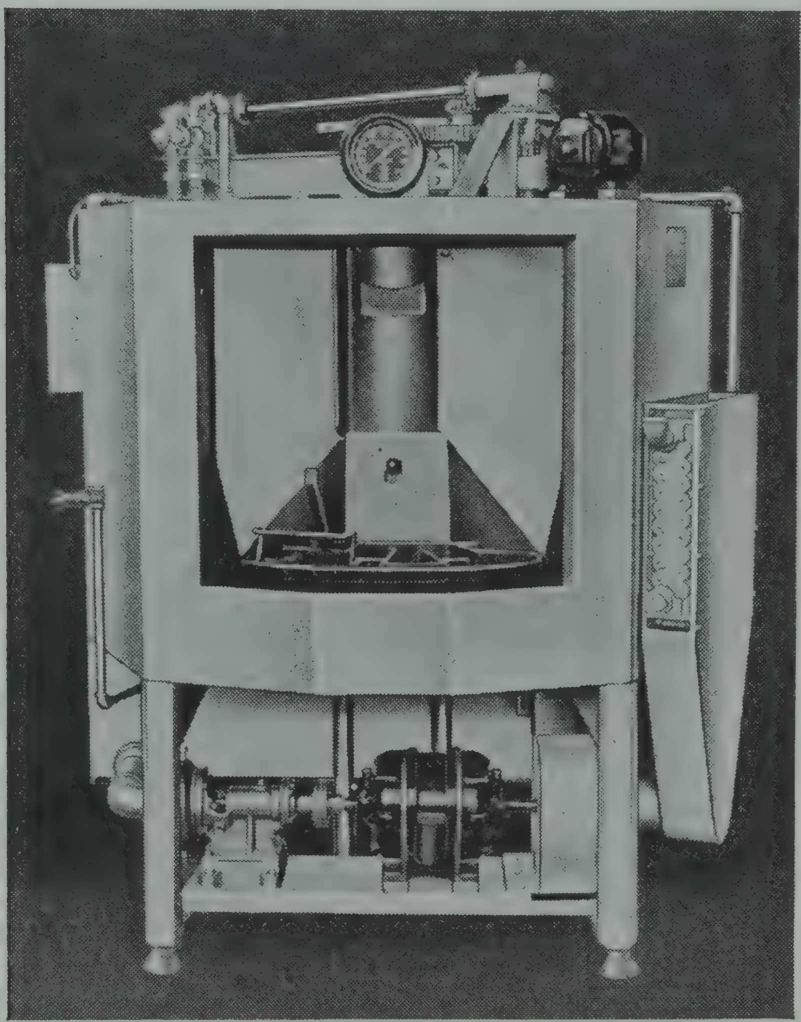


Fig. 36. Rotary can washer
Courtesy of Rice and Adams Corporation

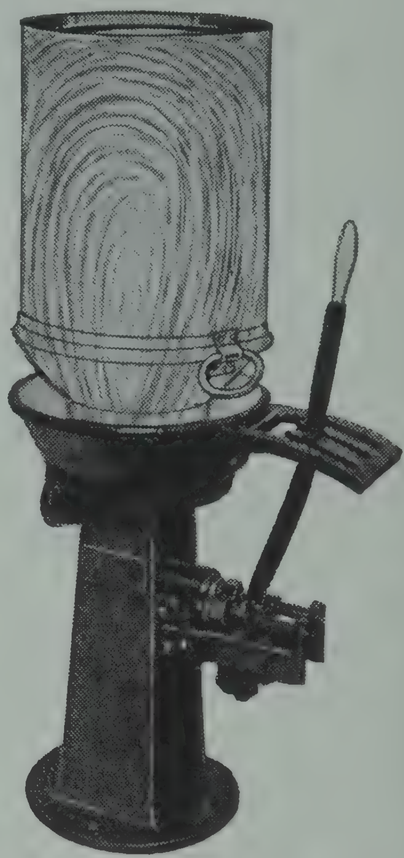


Fig. 37. Steamer for single cans
Courtesy of Creamery Package Mfg. Company

However, while practically automatic, these can washing machines and their operation are by no means fool-proof. They need attention, like most other pieces of equipment. They must be timed correctly; the temperature of rinse water and the pressure of steam must be controlled; jets for rinse water, alkali solution and steam must be kept free from clogging; jet guns, if any, must be inspected and cleaned, and valves readjusted frequently. The alkali compound used in the washing solution should readily dissolve curd and saponify fat without seriously attacking the tin on the cans. The can washer should be equipped with a dependable arrangement for the proper control of the strength of the alkali solution throughout the daily period of operation. In order to insure maximum efficiency these ma-

chines must be inspected daily, and all parts must be kept in first class operating condition.

Inspection of Cans.—One of the surest ways to accomplish efficient can washing, whether by hand or by machine, is to practice a rigid system of inspecting the cans, as they come from the can washer, or before they are returned to the farmer. By such inspection, cans that did not respond to the treatment are "spotted" and may be returned for rewashing. If there is anything wrong with the can washer or machine, the condition of the cans will reflect it and the difficulty may be corrected at once.

Can Washing at the Cream Station and Concentration Point.—The return of dry, clean, sweet-smelling cans to the farmer by the cream station or concentration point is no less important than the condition of the cans returned to him by the creamery. In most cases the volume of business at these buyers' points is too limited to justify the installation of a mechanical can washer, and the boiler capacity necessary is too limited for satisfactory operation of the can washer. In many cream stations the can washing must be done by hand. But even here the process requires the availability of hot water and preferably of some steam, and at least a simple wash tank with steam jet. The larger, properly equipped and managed cream stations usually are provided with a small boiler, wash tank and steam jet, and in a few cases with a small capacity, mechanical can washer.

There are now on the market, station can washing tanks equipped with a coal, oil, or gasoline burner, capable of supplying a limited amount of hot water and of sufficient steam to blow the cream remnants out of the can and to steam the can after washing. While these miniature can washers will not put the empty cans in as satisfactory condition as a standard mechanical can washer, their proper use will enable the cream station to return to the farmer a cleaner and more nearly sanitary can than is likely to result by hand washing on the part of the average cream station operator.

Size, Quality and Construction of Cans; Rusty and Damaged Cans.—For shipping or hauling milk the 10-gallon can is the most popular. Most farmers who ship milk have enough

of it most of the time to fill a 10-gallon can. This refers largely to creamery patrons. In the case of milk that is intended for city milk consumption, the 8-gallon can predominates in many localities. For shipping cream a smaller can is preferred. The smaller can is filled in a shorter time and encourages more frequent shipments, thus helping the creamery to secure a fresher cream. The shipping rate on the 5-gallon can also is less than that on the 10-gallon can, and since the rate is the same for part full cans as for full, it is cheaper to ship a 5-gallon can full than a 10-gallon can only part full.

Generally speaking, a well constructed can made of heavy tin plate lasts longer and gives better service than a can of light construction. However, in the case of sour cream, the acid corrodes and rusts even the best can in time. All cans with seams should have their seams well flushed with solder, so as to avoid the lodging of remnants of decaying cream in the seams at the bottom, side and shoulder.

All cans should receive a special inspection at regular intervals and cans which contain more than about one square inch of rust spots should be scoured with some good friction material, such as cement or emery powder. Cans that do not respond to this treatment and that show excessive rustiness may be put in satisfactory condition by retinning. Also, cans with loose shoulders, if they cannot be mended satisfactorily, should be removed from service.

The fact that the can is rusty indicates that the tin coating has become defective in spots and that iron is exposed. The exposed iron is acted upon by the acid and some of the other constituents of the cream, causing the formation of metallic salts, which hasten decomposition of the cream, either through chemical action, or by accelerating the action of bacteria, or enzymes, or both. Such action may lead to diverse flavor defects in butter, such as metallic, tallowy, fishy flavor, etc.

Rusty cans are objectionable also for sanitary reasons. Rust spots present a rough surface, on which remnants of milk and cream lodge readily and from which they are difficult to remove. Rust spots also retain moisture in such a way that they are difficult to dry. The tendency of rusty cans to not be perfectly clean and completely dry, makes them fertile breeding places for bacteria and causes them to become foul-smelling, and to pollute the cream and injure the butter made from it.

Replacing Old Cans by New Ones.—An effective means of maintaining a satisfactory standard of quality and condition of the cans in use is to adopt a system whereby, at definite intervals such as once every three months, a certain percentage, say one per cent, of the cans, that are in the poorest condition, is discarded. In this manner there is a constant renewal of cans and at a comparatively small cost at any one time.

Retinning Rusty Cans.—Some creameries maintain a tinshop of their own, where defective cans may be repaired and rusty cans retinned. When this can be done at a moderate expense, it is certainly a commendable practice. In many instances, however, experience has shown that the cost of retinning was out of proportion to the value of the can, and was too great to justify it.

There are now in operation firms who are specializing in repair work of his type and who dismantle old cans, retin the pieces and reassemble them so that the repaired can is practically as good as new, and at a cost materially lower than the price of a new can. In 1940 the average cost of such retinning of ten gallon cans was $1.65.

REFERENCES

1. BROWN, R. W., The World's Butter Review II, 3, 11, (1935).
2. HUNZIKER, O. F., MILLS, H. C., and SPITZER, GEO., Purdue Agr. Expt. Sta. Bul. 145, (1910).

CHAPTER X

THE NEUTRALIZATION OF SOUR CREAM

Definition.—By neutralization of cream for buttermaking, is understood the reduction of the acid in sour cream. Chemically, neutralization would mean the process of making the cream neutral, i. e., removing all the acid. This would be obviously undesirable in the case of cream intended for buttermaking. It would make butter of very inferior flavor and poor keeping quality. In fact, it would forfeit the benefits for which cream is neutralized.

In the sense used in the creamery, neutralization refers to the removal of excess acid, reducing the acidity to say approximately .1% to .3%. The term "neutralization," therefore, is a misnomer. A more correct name for this process would be the "Standardization of Cream for Acid," or "Acid Reduction of Cream." However, "neutralization" has become an established trade name, it has become an inherent part of the creameryman's vocabulary, so that, in order to avoid confusion and for the sake of clearness, it seems advisable to retain the trade term "neutralization" in this discussion.

Objects of Neutralization.—With the help of proper neutralization, the creamery aims to accomplish the following three principal objects:

1. To avoid excessive loss of fat that results from churning cream that is pasteurized while excessively sour. When sour cream is pasteurized, the casein curdles. This heat curdling entrains fat in the particles of curd. Since the bulk of the curd contained in the cream passes into the buttermilk, this entrained fat increases the buttermilk test, causing excessive loss of fat. Reduction of the acid in the sour cream by proper neutralization before pasteurization, assists in preventing heat curdling in subsequent pasteurization, and thereby largely eliminates the danger of high fat losses in the buttermilk. In the absence of pasteurization, the churning of sour cream does not increase the fat losses. When making butter from raw cream, therefore, neutralization of sour cream is of no benefit, as far as control of fat losses is concerned.

2. To guard against the production of undesirable flavors in cream which may result when cream that is high in acid is pasteurized at a high temperature. Butter made from high-acid cream, pasteurized at high temperature, usually shows an objectionable, coarse, oily-like flavor. Proper neutralization of the cream before pasteurization helps to avoid this defect.

3. To improve the keeping quality of butter made from high-acid cream. This is by far the most important objective of proper neutralization. The results of carefully conducted scientific experiments and long experience in the commercial manufacture of butter have conclusively demonstrated that salted butter made from sour cream lacks keeping quality, and is especially prone to develop fishy flavor with age. The proper reduction of the acidity in such cream greatly improves the general keeping quality of the butter and very largely eliminates the development of fishiness.

Importance of Correct Neutralization.—The process of reducing the acidity of cream has been a real help to the manufacturer of butter, who receives sour cream. This advantage is made possible by correct neutralization. Improper methods, and overneutralization, however, defeat these benefits, and are distinctly destructive to both flavor and keeping quality of the butter. They may also become a contributing cause of excessive fat losses in the buttermilk. It is, therefore, important that, where neutralization must be resorted to, it be done correctly.

Fundamentally, the addition of a neutralizer to the cream does not improve the flavor of the butter. To be sure, acid reduction assists in preventing the flavor-damaging tendency of the combined action of high acid and high pasteurizing temperature. However, the delicate flavor and fine aroma characteristic of good butter are intimately related to the acids in the cream. When neutralizing to a point sufficiently low to destroy practically all the acid, the delicate flavor usually also suffers and the resulting butter is flat and tasteless. Such butter has no pronounced flavor, it has no character, unless efforts are made to redevelop flavor and aroma by the proper use of a good starter. For this reason alone, it is not advisable to reduce the acidity to a point lower than is necessary to insure keeping quality in the butter.

Furthermore, alkalies, such as must be used as neutralizers

of cream, have themselves a flavor entirely foreign to the pleas ant flavor of good butter. Hence, the addition to the cream of neutralizer in quantities large enough to reduce the acidity t a very low point, tends to impart to the butter some of th neutralizer flavor. This tendency is obviously greatest wit butter made from cream of very high original acidity. Neu tralization to near the neutral point has the added objectio that it may lead to over-neutralization, which is damaging t both flavor and keeping quality.

However, in the case of cream with a relatively low initia acidity, neutralization to near the neutral point does not neces sarily cause neutralizer flavor in the resulting butter. Th amount of neutralizer added to such cream is too limited t seriously jeopardize its flavor.

PROCEDURE FOR ACCURATE NEUTRALIZATION

The more important requisites for accurate neutralizatio that makes possible the full realization of the desired benefits may be conveniently grouped as follows:

1. Adoption of a definite standard of churning acidity.
2. Testing correctly for acidity.
3. Correct amount of neutralizer to add.
4. Proper way of adding neutralizer to cream.
5. Checking results by re-testing for acidity.

1. Adoption of a Definite Standard of Churning Acidity.— It is the acidity of the cream at churning time that controls the flavor and keeping quality of the butter, insofar as they are affected by or depend on the acidity of the cream. The operator must, therefore, decide first of all, at what acidity the cream shall be churned. Having established his goal of churning acidity, he is then in a position to standardize his process of neutralization to a point of acid reduction that, under his conditions of operation, will yield the desired churning acidity. With this background he will have something definite and specific to work to. And, having established such a standard, uniformity of results demands that this standard be abided by.

The Maximum Churning Acidity that Insures Freedom from Chemical Deterioration of Butter with Age.—The earlier efforts to arrive at the safety limit of churning acidity for sour,

neutralized cream had for their chief purpose to guard against the development of fishy flavor in butter. It was then definitely established that for cream of average richness (about 30% fat), fishiness could be prevented with certainty by holding the churning acidity down to three-tenths per cent (.3%) acid.

Within the past decade the relation of churning acidity to keeping quality of butter, from the standpoint of prevention of age deterioration due to chemical causes, has been subjected to much additional experimental study. The results of these investigations fully confirm the earlier findings of acid limit to prevent fishy flavor. In addition, these later results emphasize the fact that low churning acidity assists in minimizing the development of flavor defects other than fishiness, resulting from chemical reactions in butter with age, particularly the type of off-flavors commonly known by the general designation of storage flavor.

These studies further demonstrated that the safe maximum limit of churning acidity varies so much with the richness of the cream that, for dependable results, it should be based on the cream serum acidity. Since the acidity of the cream is chiefly contained in the cream serum, the richer the cream in fat and therefore the less serum it contains, the greater is the acid concentration in this serum. The serum of the cream is determined by subtracting the per cent fat from 100. The serum acidity is determined by dividing the per cent acid contained in the cream by the cream serum.

Example: Cream contains 30% fat and .25% acid. What is the serum acidity?

$100 - 30 = 70\%$ cream serum.

$$\frac{.25}{.70} = .357\% \text{ serum acid.}$$

The mass of experimental evidence on relation of acidity to age deterioration of butter, due to chemical causes, indicates that such age deterioration is negligible when the serum acidity of the cream at churning time is limited to .35% acid. While a slightly higher serum acidity does not necessarily lead to serious age defects, the higher the serum acidity above this limit, the greater is the tendency of the butter to show age defects due to chemical causes.

On the basis of these findings, therefore, it appears wisdom, especially in the case of butter intended for prolonged storage,

to adopt a maximum limit of serum acidity of .35%. The seru acidity is readily expressed in terms of cream acidity (acid test by subtracting the per cent fat of the cream from 100 and mul plying the difference with the per cent serum acidity, i. e, mul ply the per cent cream serum with the per cent serum acidi desired.

Example 1. Cream tests 20% fat; a serum acidity of .35 is desired. What should be the acid test of the cream?

100 — 20 = 80; .80 × .35 = .28% acid of cream.

Example 2. Cream tests 30% fat; serum acidity of .35% desired. What should be the acid test of the cream?

100 — 30 = 70; .70 × .35 = .245% acid of cream.

Example 3. Cream tests 40% fat; a serum acidity of .35 is desired. What should be the acid test of the cream?

100 — 40 = 60; .60 × .35 = .21% acid of cream.

The above examples clearly show that, in order to chur the cream at a uniform, standard serum acidity, the corre per cent acid of the cream will vary with the richness of th cream. For the convenience of the buttermaker Table (19 has been assembled, that shows the correct churning aciditie of cream ranging in richness from 20% to 50% fat, based o a cream serum acidity of .35%. For churning acidities repre senting cream serum acidities other than .35%, see table 20.

Under reasonably normal conditions of operation, the rich ness of the cream in one and the same factory does not var

Table 19.—Churning Acidities of Creams of Different Richnesse Based on a Serum Acidity of .35%

Fat in Cream Per Cent	Churning Acidity Per Cent	Fat in Cream Per Cent	Churning Acidity Per Cent	Fat in Cream Per Cent	Churning Acidity Per Cent
20	.280	30	.245	40	.210
21	.276	31	.241	41	.206
22	.273	32	.238	42	.203
23	.269	33	.234	43	.199
24	.266	34	.231	44	.196
25	.262	35	.227	45	.192
26	.259	36	.224	46	.189
27	.255	37	.220	47	.185
28	.252	38	.217	48	.182
29	.248	39	.213	49	.178
30	.245	40	.210	50	.175

Table 20.—Percentage of Acid of Cream at Cream Serum Acidities Ranging from .15 to .45% and Fat Ranging from 20 to 40%

Fat in Cream %	Per Cent Acid in Cream of Different Serum Acidities						
	Serum Acidities						
	.15 % Acid	.20 % Acid	.25 % Acid	.30 % Acid	.35 % Acid	.40 % Acid	.45 % Acid
20	.12	.16	.20	.24	.28	.32	.36
21	.118	.158	.197	.237	.276	.316	.355
22	.117	.156	.195	.234	.273	.312	.351
23	.115	.154	.192	.231	.269	.308	.346
24	.114	.152	.19	.228	.266	.304	.342
25	.112	.15	.187	.225	.262	.3	.337
26	.111	.148	.185	.222	.259	.296	.333
27	.109	.146	.182	.219	.255	.292	.328
28	.108	.144	.18	.216	.252	.288	.324
29	.106	.142	.177	.213	.248	.284	.319
30	.105	.14	.175	.21	.245	.28	.315
31	.103	.138	.172	.207	.241	.276	.31
32	.102	.136	.17	.204	.238	.272	.306
33	.1	.134	.167	.201	.234	.268	.301
34	.099	.132	.165	.198	.231	.264	.297
35	.097	.13	.162	.195	.227	.26	.292
36	.096	.128	.16	.192	.224	.256	.288
37	.094	.126	.157	.189	.22	.252	.283
38	.093	.124	.155	.186	.217	.248	.279
39	.091	.122	.152	.183	.213	.244	.274
40	.09	.12	.15	.18	.21	.24	.27

vary greatly between churnings, nor from day to day, so that nothing would be gained by trying to adjust the churning acidity of each churning to its particular richness. The churning acidities given in Table (19) are sufficiently below the danger point to render harmless such minor deflections from the established standard of the serum acidity (.35%), as might be caused by slight variations in per cent of fat between churnings. However, if the cream from a certain supply territory is much richer than the remainder of the cream supply, it will be wisdom to use a correspondingly lower churning acidity for the richer cream than for the other churnings.

Point to Which to Neutralize in Order for the Cream to have the Desired Churning Acidity.—If the cream is churned without the addition of starter and without ripening, there is no appreciable increase in acidity between time of neutralization and time of churning. This is true even if the cream is held overnight, provided that it was pasteurized efficiently and cooled to and held at churning temperature or below (a temperature

low enough to yield a normally firm body of butter). This fact does not eliminate the necessity, however, of retesting the cream for acid at churning time, in order to prevent the possibility of too high churning acidity resulting from accidental or unknown causes.

If starter is added to the cream at churning time, the churning acidity will increase slightly. Each per cent of starter added raises the acidity of the cream approximately .005 per cent. Therefore, in order to hold the acidity down to the desired churning acidity when starter is used, it is necessary to neutralize to a correspondingly lower acidity. For example, if the churning acidity aimed at is .25%, and 7% of starter is added to the cream at churning time, the cream should be neutralized to $.25 - (7 \times .005) = .215$ per cent acid.

If it is intended to ripen the cream, it may be neutralized to a considerably lower per cent acid, and the temperature and period of ripening so adjusted as to attain the desired churning acidity. Or, the ripening may be carried to a higher acidity, and the cream neutralized back to the desired churning acidity immediately before churning.

In the case of cream with a high original acidity, such as cream containing over .6% acid, it is usually not desirable to neutralize to a point lower than .12 to .15% acid, because of the danger of giving the butter an objectionable neutralizer flavor. Furthermore, high acid cream that is neutralized to acidities much lower than those indicated in Table (19), even when relatively free from neutralizer flavor, is uninvitingly flat to taste, unless the cream is ripened back with the help of a good starter. In the absence of cream ripening or the addition of starter, high acid cream will yield butter with a more pleasing flavor, when neutralizing to a point no lower than is necessary to insure freedom from early age deterioration due to chemical causes. For high acid cream of average richness, this is accomplished by neutralization to within a range of about .20 to .25% acid.

Cream with less than .6% original acidity may be neutralized to advantage to a somewhat lower acidity, such as .10 to .12% acid. Low neutralization is of some assistance in minimizing certain types of off flavors present in the cream, particularly metallic flavor. In fact, where practicable, it is advantageous to neutralize metallic flavored cream, even if high in acid, separately to near the neutral point, then mix it with unneutralized

cream that is not metallic and then neutralize and pasteurize the mixture in the regular manner. This assists in minimizing the metallic flavor without imparting an objectionable neutralizer flavor.

The addition of the chemically correct amount of neutralizer to the cream does not always reduce the acidity of the cream exactly to the expected per cent acid. This is often due to the presence of carbon dioxide in the cream, or added with the neutralizer. The completeness of the expulsion of carbon dioxide and other volatilizable acids depends largely upon the process of pasteurization. High temperature flash pasteurization, and treatment of the cream under vacuum for the purpose of removing objectionable odors and flavors, usually reduce the acidity to a somewhat lower point than does vat pasteurization, as explained in later paragraphs.

2. **Testing Correctly for Acidity.**—It is obvious that the accuracy of neutralization centers fundamentally on the accuracy of the acid test. Reduction of acidity to a definite standard point need not be expected, unless the operator is able to determine the correct per cent acid contained in the cream before neutralization. Numerous simple and accurate acid tests are available for the purpose. They all refer to the use of a dilute solution (usually a deci-normal solution) of sodium hydroxide and phenolphthalein as indicator. Detailed directions for these tests are given in Chapter XXV on "Factory Tests."

Representative Sample for Acid Test.—Care is necessary to insure samples of cream that are truly representative of the acidity of the cream that is to be neutralized. Experimental data show that the acidity in different parts of the forewarmer may vary within wide limits. Thorough mixing of the entire batch of cream is necessary to make the cream uniform in acid content throughout at the time the sample for the acid test is taken. This is just as important as when sampling cream for the fat test. For accurate sampling of cream containing air and gas see Chapter XXV on "Factory Tests."

Accurate Weight of Cream in Vat—Determination of the exact amount of neutralizer of known strength to add to the cream to reduce the acidity to the desired point demands knowledge of the correct pounds of cream that must be neutralized. In the small creamery the weight of the cream in the vat or

forewarmer is usually determined most readily from the cream receipts, as recorded on the daily milk and cream sheet. In the majority of creameries this method, though accurate, is often not convenient and the weight of the cream in the vat is determined by measuring the depth of the cream with an accurately graduated measuring stick, calibrated to show the pounds or gallons of cream in the vat, or by the use of a suitable cream gauge attached to the vat.

Effect of High-Acid Cream on Accuracy of Neutralization.—High-acid cream, such as is characteristic of some of the cream received during the hot weather months, usually contains considerable carbon dioxide and other volatile acidity due to bacterial fermentation.

In the acid test with sodium hydroxide and phenolphthalein, the carbon dioxide present in the unneutralized cream sample reacts acid to the phenolphthalein indicator. This causes the acid test of such cream to be erroneously high. Consequently the amount of neutralizer added is in excess of that needed. Since the bulk of the carbon dioxide escapes from the cream during subsequent pasteurization, the re-test of such cream at churning time will show a lower acidity than the intended churning acidity.

Discrepancies in results of neutralization due to the presence of carbon-dioxide in the raw, unneutralized, high-acid cream may be avoided by heating the sample of unneutralized cream to the boiling point before it is tested for acid. It is advisable to boil all samples of raw cream with an acidity of .65% or over.

3. **Correct Amount of Neutralizer to Use.**—The amount of neutralizer to add in order to reduce the acidity of the cream to the desired point obviously depends, aside from the amount of acid that must be neutralized, on the alkaline strength of the neutralizer. The operator must, therefore, know the actual neutralizing strength of whatever neutralizer he may use. He must then calculate the exact amount required to reduce the acidity in any given volume of cream of any acidity to the per cent acid desired. This is the only dependable way of determining the correct amount of neutralizer to add. No other method will yield reliable and uniformly accurate results. For neutralizing strength of different neutralizers see later paragraphs.

4. The Proper Way of Adding the Neutralizer to the Cream.—Most alkalies and compounds suitable as cream neutralizers are available on the market in dry form. They should not be added to the cream in this form, as their concentrated action on the cream is too severe. They should be dissolved or emulsified in clean water, added in proper dilution, the solution must be distributed quickly and uniformly throughout the entire batch of cream, and mixed thoroughly with the cream. Dilution should be at the rate of 1 to 1½ gals. of water per pound of dry neutralizer.

The distribution of the neutralizer is readily done by spraying from a trough with perforated bottom, from a perforated pipe, or from a sprinkling can. Spraying onto the surface of the well-agitated cream in the vat or forewarmer is usually preferable to attempts of injecting the neutralizer into the cream through a perforated pipe installed below the surface of the cream. While the neutralizer is added, the cream should be agitated vigorously and continuously. Agitation of the cream is preferably continued for 5 to 10 minutes after neutralization and before the cream is exposed to pasteurizing temperature.

The temperature of the cream at the time of neutralization is best held down to 85 to 90° F. This is high enough to reduce the cream to a smooth consistency suitable for neutralization, and low enough to prevent abnormal heat-curdling of the sour cream. The cream should not be held at this temperature unduly long, as such holding tends to cause oiling off and mealy butter. It is undesirable also because of the danger of developing oily-metallic flavor. If the factory routine does not permit of pasteurization promptly after neutralization is completed, it is advisable to cool the cream to about 65° F. A still better procedure is to defer "dumping" of the cream until the factory is ready to follow neutralization with pasteurization without delay.

The above precautions in connection with method of neutralization and the handling of the cream up to the pasteurizer are essential, if efficiency of neutralization, protection of butter against neutralizer flavor, oily-metallic flavor and mealy body, avoidance of pasteurizing difficulties, and prevention of excessive fat losses in the buttermilk, are to be assured.

5. Checking Results of Neutralization by Retesting for Acidity.—Check tests for acidity immediately after neutraliza-

tion are of little value and the results of such tests may be misleading.

In the case of Lime and Magnesia neutralizers the neutralizing action is so slow, that it is not complete until after pasteurization and cooling. Acid tests made immediately after neutralization and before pasteurization, therefore, have no value.

In the case of soda neutralizers, most of which are carbonates or bicarbonates, or a combination of both, carbon dioxide is liberated and this reacts acid toward the phenolphthalein indicator. The effect of these neutralizers on the acidity of the cream toward phenolphthalein, therefore, depends mainly on their decomposition and on the loss of carbon dioxide from the mixture. The expulsion of the carbon dioxide present in the cream is largely accomplished during pasteurization. A reasonably correct check test can be obtained from the cream before pasteurization, however, by boiling the sample before titration.

The most important time for retesting the cream for acid is just before churning. It is the churning acidity that determines to a large extent the acidity of the butter. The acidity of the butter in turn exerts a controlling influence on the presence or absence of chemical action that causes butter deterioration, it controls the keeping quality of the butter.

Neutralization is an operation which, if performed accurately and with the intelligent consideration of the peculiarities of the type of neutralizer used, and of the condition of the cream to be neutralized, yields definite acid reduction to a predetermined point. Its results are known in advance and should require no checking by retests. The possibility of errors in technique, and the uncertain influence of the use of starter and the time and temperature of holding the cream, however, make the definite determination of the final churning acidity by the use of a retest indispensable.

Thus, in the case the acidity has risen beyond the desired churning acidity, the retest reveals this fact and supplies the basis for calculating the additional amount of neutralizer required to adjust the churning acidity to the desired point.

KIND AND SUITABILITY OF CREAM NEUTRALIZERS

Neutralizers, in order to accomplish the purpose for which they are used in the creamery, must have alkaline properties.

They must be alkalies, alkaline earths, or their carbonates. An alkali is a substance that has the property of neutralizing acids, forming salts with them. The neutralizers used for reducing acidity in cream belong to either one or the other of two groups; namely, lime neutralizers, and soda neutralizers.

Lime Neutralizers.—The principal constituent of the majority of lime neutralizers is calcium. Many of the lime neutralizers available for cream neutralization also contain some magnesium. The magnesium content of limes of different strata of lime rock varies. The various commercial lime neutralizers differ from one another chiefly with respect to the proportion of calcium and magnesium they contain. They are conveniently placed in three groups, as follows:

1. Low-Magnesium limes, containing 5% or less of magnesium. A well-known brand of creamery lime belonging to this group is Peerless lime.

2. Medium-Magnesium limes, containing about 30 to 35% magnesium. To this group belong such brands as Kelley Island lime, Neutra-Lac, and Neutra-Lime.

3. High-Magnesium limes, containing about 45 to 55% magnesium. Allwood lime is an outstanding representative of this group.

All-Magnesium limes in the form of magnesium oxide and magnesium carbonate, are also available. They are artificially prepared limes and demand a higher price than the natural limes. Their effect on the flavor of cream and butter, however, is outstandingly favorable. Calcium carbonate lime is unsuitable for cream neutralization by reason of its low solubility, low alkalinity, and slow action.

The several brands of low- and medium-magnesium limes listed in the foregoing classification are slaked limes. Their calcium is present as calcium hydrate, and their magnesium as magnesium oxide. The high-magnesium Allwood lime is unslaked, both the calcium and magnesium being present in the oxide form.

In general, the medium- and high-magnesium limes react somewhat more satisfactorily in the cream than the low-magnesium limes. The higher the magnesium oxide content of lime the greater is its alkalinity and its neutralizing strength.

Soda Neutralizers.—The soda neutralizers commonly used in the creamery are:

1. Bicarbonate of soda, or baking soda ($NaHCO_3$).

2. Carbonate of soda, or soda ash (Na_2CO_3).

3. Mixtures of baking soda and soda ash, such as Sodium Sesquicarbonate, also Neutralene, Nat'l Neut, and Wyandotte C. A. S.

4. Within recent years, mixed soda neutralizers containing sodium hydroxide, or caustic soda, have also been introduced. Usually these neutralizers contain part sodium carbonate and part sodium hydroxide.

Comparative Merits of Lime and Soda Neutralizers.—The more outstanding characteristics of these neutralizers are listed below:

1. **Purity.**—The neutralizers of either group are free from organic impurities. According to the work of Walts and Libbert,[1] the total impurities found in soda neutralizers amounted to less than 0.1 of one per cent. Lime neutralizers occasionally contain objectionable insoluble matter in the form of calcium carbonate, clay, sand, etc. These impurities are closely associated with the strata from which the rock lime is mined, and with the kiln in which it is burned. It is wisdom for the creamery, therefore, to trace its lime supply back to the kiln that produced it, and in case the lime has proved of satisfactory purity and fineness, to insist on receiving all future shipments of lime from the same kiln.

2. **Solubility.**—Soda neutralizers are completely soluble in water, and they dissolve readily. Their action on the acid in the cream is practically instantaneous. These attributes facilitate their handling and make for accuracy of results. Lime neutralizers are only slightly soluble and their neutralizing action is much slower.

3. **Action on Casein.**—Soda neutralizers have a softening and solvent action on the casein. This property assists in minimizing the clogging of strainers in the presence of high temperature treatment. With lime neutralizers the tendency lies in the direction of precipitating and granulating the casein, causing the cream to thicken. This becomes objectionable when a large amount of neutralizer must be used, such as in the case

of very high-acid cream that is neutralized to a relatively low point (.15% acid or below), and especially when followed by high temperature flash pasteurization. The cream thus behaves sluggishly in the pasteurizer, moving over the heating surface slowly, intensifying the burning-on tendency, and augmenting the danger of giving the butter a scorched, coarse, bitter, limy flavor. In the case of vat pasteurization at 145 to 160° F. for 30 minutes, this thickening tendency is largely absent.

4. **Acid Reduction.**—Lime neutralizers have the peculiarity that calcium has a natural affinity for the casein. It acts on the casein acid first. Due to its very low solubility, the lime neutralizer (milk of lime) is principally a mechanical emulsion of insoluble lime particles in water. Being attracted by the casein, lime particles attach themselves mechanically to casein particles, and to the extent to which a portion of the lime becomes thus "tied-up" with the casein, its alkalinity appears not to be available for neutralization of the serum acid. This calcium-casein affinity, therefore, detracts somewhat from the reduction of the titratable acidity of the cream. Analyses by Hunziker and Hosman[2] of the constituents of cream before and after neutralization to 0.26% acid showed that the increase in calcium content of the curd portion was approximately five times greater than that of the serum portion of the neutralized cream. Laboratory experiments and factory trials by the same investigators further demonstrated that while in aqueous solutions of lactic acid the neutralizing action of lime is complete, in sour cream the acid reduction is only about 80 to 85% of what it should be on the basis of theoretical calculations. In order to accomplish the desired acid reduction in sour cream when using lime neutralizer, it is necessary, therefore, to increase the amount of lime added by approximately 20% in excess of the amount calculated on the basis of its theoretically true alkalinity. In the formula and tables assembled for cream neutralization in this chapter, this correction is fully provided for.

Soda neutralizers do not surrender any portion of their alkalinity to the casein. They act on the serum acid first. Since proper neutralization is not carried to or beyond the neutral point, their neutralizing action in cream corresponds with their theoretical alkalinity, provided that subsequent treatment (pas-

teurization) of the neutralized cream is of a nature to accomplish complete decomposition of the neutralizer and the expulsion of the carbon dioxide from the mixture.

If, however, the decomposition of the bicarbonate or the carbonate neutralizer is not complete, and carbon dioxide remains in the cream, then the acid test of the soda-neutralized cream is erroneously high, because the carbon dioxide is not alkaline to phenolphthalein. In such case cream neutralized beyond the neutral point may still react acid in the test, as shown by the work of McDowall and McDowall.[3] For these reasons retests of vat pasteurized cream that was neutralized with soda neutralizer are invariably erroneously high, unless the sample used for the test is first boiled.

5. **Foaming Effect.**—Lime neutralizers do not cause cream to foam. Soda neutralizers, especially the bicarbonate, and the carbonate to a lesser extent, cause violent foaming, particularly in the case of high-acid cream.

6. **Neutralizing Strength.**—Soda neutralizers are weaker alkalies than the lime neutralizers commonly used. About twice as many pounds of the former are required to neutralize a given amount of acid, as of the latter.

7. **Material Cost.**—Lime neutralizers are by far the cheapest. Their cost, pound for pound, is lower than that of soda neutralizers. This, together with their higher alkaline strength, makes their material cost approximately one-third of that of soda neutralizers.

8. **Effect on Texture of Butter.**—With cream of moderate acidity neither type of neutralizer, when properly used, has any noticeable effect on the texture of butter. In the case of high-acid cream, especially when neutralized to a low point, there is a tendency for butter made from lime neutralized cream to have a somewhat less smooth texture.

9. **Effect on Flavor of Butter.**—When used properly, and with cream of moderate acidity, neither neutralizer has any advantage over the other. In the case of high-acid cream, and especially when carrying neutralization to near the neutral point, there is a tendency of either neutralizer, when used exclusively, to give the butter a noticeable neutralizer flavor. In such case butter from all-lime-neutralized cream may show a coarse, limy

lavor, while that from all-soda-neutralized cream is prone to how a soapy type of neutralizer flavor.

Double Neutralization with Lime and Soda.—The use of oth lime and soda neutralizer has for its purpose to avoid the ntense effect on flavor of a large amount of one neutralizer, in he case of high-acid cream. The common practice in such case s to neutralize with lime to about 0.4% acid, and then continue acid reduction to the desired final point with soda neutralizer.

While there appear to be no available experimental data hat would show the beneficial effect of double neutralization on the flavor of the resulting butter, experience in commercial outter manufacture points definitely in favor of double neutralization of high-acid cream, especially when neutralizing to a relatively low point.

NEUTRALIZING DIRECTIONS FOR FACTORY USE

The correct, required amount of dry neutralizer may be weighed out for each individual churning, or a neutralizer mix (solution or emulsion) of known strength may be prepared in advance and the required amount of this mix measured for each churning of cream. In either case, it is important to add the neutralizer to the cream in properly diluted form.

Weighing the Dry Neutralizer for Individual Churnings.—The correct amount of dry neutralizer required to reduce the acidity in 100 lbs. of cream, 0.01%, is shown in Table 21.

The individual brands of neutralizers listed under each group in Table 21 vary slightly in their neutralizing strength. Slight variations also occur between different shipments of the same brand. The neutralizing strength given for each group, however, agrees sufficiently closely with that of the individual brands listed under their respective group, to fall well within the unavoidable limit of error of the neutralizing operation itself. The figures given in table 21, therefore, may be considered correct for all practical purposes of cream neutralization.

Calculation of Amount of Dry Neutralizer Required to Use.—Table 21 indicates the pounds of dry neutralizer that will reduce the acidity in 100 lbs. of cream 0.01%. To determine the pounds of dry neutralizer required to neutralize any size

Table 21.—Amount of Dry Neutralizer Required to Neutralize 0.01% Acid in 100 Lbs. of Cream

Group and Brand of Neutralizer	Dry Neutralizer Required to Neutralize 0.01% Acid in 100 Lbs. of Cream, Pounds
Low-Magnesium lime (less than 5%Mg0), such as Peerless lime[1]	.00500
Medium-Magnesium limes (30 to 35% Mg0), such as Kelley Island[2], Neutra-Lac[3], Neutra-Lime[4]	.00411
High-Magnesium limes (45 to 55% Mg0), such as Allwood lime[5]	.00300
K. & M. Magnesium Oxide lime[6]	.00329
K. & M. Magnesium Carbonate lime[6]	.00666
Sodium bicarbonate (baking soda)	.00934
Sodium carbonate (soda ash)	.00671
Mixtures of Baking soda and Soda ash, such as Sesquicarbonate, Neutralene[7], Nat'l Neut[8]	.00845
Wyandotte C. A. S.[9]	.00776

[1]Hunkins-Willis Lime & Cement Co., St. Louis, Mo.
[2]Kelley Island Lime and Transport Co., Cleveland, Ohio.
[3]The Toledo-Baltimore Bottle Cap Co., Toledo, Ohio.
[4]The Western Lime and Cement Co., Milwaukee, Wis.
[5]Allwood Sales Co., Manitowoc, Wis.
[6]Keasbey and Mattison Co., Ambler, Pa.
[7]Dairy Chemical Co., Manson, Ia.
[8]National Soap & Chemical Co., Minneapolis, Minn.
[9]J. B. Ford & Co., Wyandotte, Mich.

churning of any given acidity to the desired point, deduct the per cent acid desired from the per cent acid present, and multiply the difference by the pounds of cream times the factor (the figure indicated for the respective neutralizer in Table 21). (% acid in cream — % acid desired) $\times$ lbs. cream $\times$ factor = lbs. neutralizer required.

Example:

Kelley Island lime is used. 2300 lbs. of cream testing 0.6% acid are to be neutralized to 0.21% acid. How much dry neutralizer is required?

Answer:

(.60 — .21) $\times$ 2300 $\times$ .00411 = 3.68 lbs. dry neutralizer is required.

Before adding the neutralizer to the cream, it should be mixed with water at the rate of 1 to 1½ gals. of clean water for each pound of neutralizer. Lime neutralizer should be stirred until it has a smooth, creamy, homogeneous consistency, free from lumps. Soda neutralizer should be completely dissolved in the water.

Making-Up and Use of Neutralizer Mix.—Most creameries with more than one churning per day, prefer to make up a concentrated neutralizer solution or mix in bulk, for use in a number of churnings. This method has been found practical, accurate and time saving. It eliminates the time-consuming and generally disagreeable job of weighing out and dissolving or emulsifying the dry neutralizer for each churning separately. The measuring of the prepared solution is done more conveniently and more rapidly than the weighing and dissolving. Valuable time is saved when the operator has the least time to spare. The neutralizer solution can be made up in such quantity as to last a week or longer, and it can be prepared at a time of the day that will not conflict with the busy factory routine. In the case of lime neutralizer, it has the added advantage of giving the lime more time to break down in the water, mellowing the texture of the lime particles and improving their reaction in the cream.

Some creameries use large containers for their stock solution of neutralizer, such as 100 gal. tanks or larger, with mechanical agitator. Others prefer to use 10 gal. cans for this purpose. Regardless of type or size of container, in order to insure accurate cream neutralization the neutralizer mix, or stock solution must be of a definitely known strength, and this in turn requires knowledge of the correct amount of dry neutralizer to use for

Table 22.—Amount of Dry Neutralizer Required for 10 Gallons of Neutralizer Solution

Group and Brand of Neutralizer	Pounds of Dry Neutralizer Required for 10 Gallons of Neutralizer Solution
Low Magnesium lime (less than 5% Mg0), such as Peerless lime	24 lbs.
Medium-Magnesium limes (30 to 35% Mg0), such as Kelley Island, Neutra-Lac, Neutra-Lime	20 lbs.
High-Magnesium limes (40 to 55% Mg0), such as Allwood lime	14.6 lbs.
K. & M. Magnesium oxide lime	16 lbs.
K. & M. Magnesium carbonate lime	32 lbs.
Sodium bicarbonate (baking soda)	46 lbs.
Sodium carbonate (soda ash)	33 lbs.
Mixtures of Baking soda and Soda ash, such as sodium sesquicarbonate, Neutralene, Nat'l Neut.	41 lbs.
Wyandotte C. A. S	38 lbs.

making up a given volume of stock solution. Since the alkaline strength of neutralizers varies with type and brand, the amount required to yield a uniform strength of neutralizer stock solution must necessarily vary also according to kind of dry neutralizer used. Table 22 gives the correct amount of each of the groups of neutralizers commonly used, that is required to make up 10 gallons of neutralizer solution of the correct neutralizing strength.

When using the amount of dry neutralizer of any group or brand listed in Table 22, with enough water to secure 10 gallons of neutralizer solution, the reduction of 0.01% acid in 100 lbs. of cream requires 0.01644 pint of neutralizer solution. Hence (% acid in cream — % acid desired) $\times$ lbs. of cream $\times$ 0.01644 = pints of neutralizer solution required.

Example:

2000 lbs. of cream testing 0.65% acid is to be neutralized to 0.25% acid. How much neutralizer solution must be used?

Answer:

$(.65 - .25) \times 2000 \times .01644 =$ 13 pints of neutralizer solution required.

Proof:

For simplicity's sake it is assumed that the neutralizer solution consists of sodium bicarbonate in water. As shown in Table 22, 10 gals. or 80 pints of the solution require 46 lbs. dry $NaHCO_3$.

84 parts of $NaHCO_3$ neutralize 90 parts of lactic acid, therefore, to neutralize .01% acid in 100 lbs. cream requires $\frac{84 \times .01}{90} =$ .00934 lb. $NaHCO_3$. Hence the total amount of dry $NaHCO_3$ required to neutralize the acid in this example is:

$$(.65 - .25) \times 2000 \times .00934 = 7.472 \text{ lbs.}$$

1 pint neutralizer solution contains $\frac{46}{80} = .575$ lbs. $NaHCO_3$.

7.472 lbs. dry $NaHCO_3$ require $\frac{7.472}{.575} =$ 13 pints neutralizer solution, as shown in Table 23.

In order to eliminate the necessity of calculating the amount of neutralizer solution required for each churning, "Neutralizing Table 23" has been prepared for creamery use. This table gives the pints of neutralizer solution required to neutralize cream to .25% acid. The percentages of cream acid are shown across the top, and the pounds of cream in the columns at the extreme left and right. The intersections of the columns of the percentages of acid and the pounds of cream indicate the pints of neutralizer solution required to reduce the acidity to 0.25%. This neutralization table—Table 23—applies to the use of all groups and brands of neutralizers listed in Table 22.

Neutralizing Table 23 is applicable also to neutralization to any point other than 0.25% acid, by making a corresponding shift of the percentages of acid at the top. Thus, for each 0.01% acid reduction below 0.25%, the percentages of acid at the top are lowered 0.01%. If it is desired to neutralize to 0.15% acid, for instance, the top percentages of acid are lowered 0.10 points, causing them to read from left to right as follows:

.17 .19 .21 .23 .25 .27 .29 .31 .33 .35, etc., instead of
.27 .29 .31 .33 .35 .37 .39 .41 .43 .45, etc.

The neutralizer solution prepared in accordance with Table 22 is too concentrated to add to the cream. The measured amount of solution required, as indicated in Table 23, should be diluted with an equal amount of water before it is added to the cream.

Neutralizing Precautions.—In order to secure the desired results, i. e., accurate acid reduction, absence of objectionable neutralizer flavor and of excessive fat losses, make sure of the correctness of weight of cream and acid test, do not heat the sour cream above 85 to 90° F. before neutralization, use the correct amount of neutralizer in properly diluted form, distribute it evenly over the cream, and continue agitation of the neutralized cream for 5 to 10 minutes before starting to pasteurize.

REFERENCES

1. WALTS, C. C., and LIBBERT, S. S., Ark. Agr. Expt. Sta. Bul. 249, (1930).
3. HUNZIKER, O. F., and HOSMAN, D. FAY, The Butter Industry 1st ed. pp. 161-171, (1920).
3. McDOWALL, F. H., and McDOWALL, A. K. R., N. Z. Dairy Res. Inst. Publ. 101, (1937).

Table 23.—Neutralizing Table.—Pints Neutralizer Solution Required to Reduce Acidity to .25%.

Pounds of Cream	PERCENT ACID IN CREAM																					Pounds of Cream
	.27	.29	.31	.33	.35	.37	.39	.41	.43	.45	.47	.49	.51	.53	.55	.57	.59	.61	.63	.65	.67	.69	
100								.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	100
200				.5	.5	.5	.5	.5	.5	.5	.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5	200
300			.5	.5	.5	.5	.5	1.0	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	300
400		.5	.5	.5	.5	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.5	2.5	2.5	3.0	3.0	400
500		.5	.5	.5	1.0	1.0	1.0	1.5	1.5	1.5	2.0	2.0	2.0	2.5	2.5	2.5	3.0	3.0	3.0	3.5	3.5	3.5	500
600		.5	.5	1.0	1.0	1.0	1.5	1.5	2.0	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.5	3.5	4.0	4.0	4.0	4.5	600
700		.5	.5	1.0	1.0	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.5	3.5	4.0	4.0	4.5	4.5	5.0	5.0	700
800	.5	.5	1.0	1.0	1.5	1.5	2.0	2.0	2.5	2.5	3.0	3.0	3.5	3.5	4.0	4.0	4.5	4.5	5.0	5.5	5.5	6.0	800
900	.5	.5	1.0	1.0	1.5	2.0	2.0	2.5	2.5	3.0	3.5	3.5	4.0	4.0	4.5	4.5	5.0	5.5	5.5	6.0	6.0	6.5	900
1000	.5	.5	1.0	1.5	1.5	2.0	2.5	2.5	3.0	3.5	3.5	4.0	4.5	4.5	5.0	5.5	5.5	6.0	6.5	6.5	7.0	7.0	1000
1100	.5	.5	1.0	1.5	2.0	2.0	2.5	3.0	3.5	3.5	4.0	4.5	4.5	5.0	5.5	6.0	6.0	6.5	7.0	7.0	7.5	8.0	1100
1200	.5	1.0	1.0	1.5	2.0	2.5	3.0	3.0	3.5	4.0	4.5	4.5	5.0	5.5	6.0	6.5	6.5	7.0	7.5	8.0	8.5	8.5	1200
1300	.5	1.0	1.5	1.5	2.0	2.5	3.0	3.5	4.0	4.5	4.5	5.0	5.5	6.0	6.5	7.0	7.5	7.5	8.0	8.5	9.0	9.5	1300
1400	.5	1.0	1.5	2.0	2.5	3.0	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.0	9.5	10.0	1400
1500	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	1500
1600	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	1600
1700	.5	1.0	1.5	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.5	1700
1800	.5	1.0	2.0	2.5	3.0	3.5	4.0	4.5	5.5	6.0	6.5	7.0	7.5	8.5	9.0	9.5	10.0	10.5	11.5	12.0	12.5	13.0	1800
1900	.5	1.5	2.0	2.5	3.0	4.0	4.5	5.0	5.5	6.5	7.0	7.5	8.0	8.5	9.5	10.0	10.5	11.5	12.0	12.5	13.0	13.5	1900
2000	.5	1.5	2.0	2.5	3.5	4.0	4.5	5.5	6.0	6.5	7.0	8.0	8.5	9 0	10.0	10.5	11.0	12.0	12.5	13.0	14.0	14.5	2000
2100	.5	1.5	2.0	3.0	3.5	4.0	5.0	5.5	6.0	7.0	7.5	8.5	9.0	9.5	10.5	11.0	11.5	12.5	13.0	14.0	14.5	15.0	2100
2200	.5	1.5	2.0	3.0	3.5	4.5	5.0	6.0	6.5	7.0	8.0	8.5	9.5	10.0	11.0	11.5	12.5	13.0	13.5	14.5	15.0	16.0	2200
2300	1.0	1.5	2.5	3.0	4.0	4.5	5.5	6.0	7.0	7.5	8.5	9.0	10.0	10.5	11.5	12.0	13.0	13.5	14.5	15.0	16.0	16.5	2300
2400	1.0	1.5	2.5	3.0	4.0	4.5	5.5	6.5	7.0	8.0	8.5	9.5	10.5	11.0	12.0	12.5	13.5	14.0	15.0	16.0	16.5	17.5	2400
2500	1.0	1.5	2.5	3.5	4.0	5.0	6.0	6.5	7.5	8.0	9.0	10.0	10.5	11.5	12.5	13.0	14.0	15.0	15.5	16.5	17.5	18.0	2500
2600	1.0	1.5	2.5	3.5	4.5	5.0	6.0	7.0	7.5	8.5	9.5	10.5	11.0	12.0	13.0	13.5	14.5	15.5	16.0	17.0	18.0	19.0	2600
2700	1.0	2.0	2.5	3.5	4.5	5.5	6.0	7.0	8.0	9.0	10.0	10.5	11.5	12.5	13.5	14.0	15.0	16.0	17.0	18.0	19.0	20.0	2700
2800	1.0	2.0	3.0	3.5	4.5	5.5	6.5	7.5	8.5	9.0	10.0	11.0	12.0	13.0	14.0	14.5	15.5	16.5	17.5	18.5	19.5	20.5	2800
2900	1.0	2.0	3.0	4.0	5.0	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.0	16.0	17.0	18.0	19.0	20.0	21.0	2900
3000	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	17.5	18.5	19.5	20.5	21.5	3000
3100	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5	22.5	3100
3200	1.0	2.0	3.0	4.0	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	3200
3300	1.0	2.0	3.5	4.5	5.5	6.5	7.5	8.5	10.0	11.0	12.0	13.0	14.0	15.0	16.5	17.5	18.5	19.5	20.5	22.5	23.0	24.0	3300
3400	1.0	2.0	3.5	4.5	5.5	6.5	8.0	9.0	10.0	11.0	12.5	13.5	14.5	15.5	17.0	18.0	19.0	20.0	21.5	22.5	23.5	24.5	3400
3500	1.0	2.5	3.5	4.5	6.0	7.0	8.0	9.0	10.5	11.5	12.5	14.0	15.0	16.0	17.5	18.5	19.5	20.5	22.0	23.0	24.0	25.5	3500
3600	1.0	2.5	3.5	4.5	6.0	7.0	8.5	9.5	10.5	12.0	13.0	14.0	15.5	16.5	18.0	19.0	20.0	21.5	22.5	23.5	25.0	26.0	3600
3700	1.0	2.5	3.5	5.0	6.0	7.5	8.5	10.0	11.0	12.0	13.5	14.5	16.0	17.0	18.0	19.5	20.5	22.0	23.0	24.5	25.5	27.0	3700
3800	1.5	2.5	4.0	5.0	6.5	7.5	8.5	10.0	11.5	12.5	13.5	15.0	16.0	17.5	18.5	20.0	21.5	22.5	24.0	25.0	26.0	27.5	3800
3900	1.5	2.5	4.0	5.0	6.5	7.5	9.0	10.5	11.5	13.0	14.0	15.5	16.5	18.0	19.0	20.5	22.0	23.0	24.5	25.5	27.0	28.0	3900
4000	1.5	2.5	4.0	5.5	6.5	8.0	9.0	10.5	12.0	13.0	14.5	16.0	17.0	18.5	19.5	21.0	22.5	23.5	25.0	26.5	27.5	29.0	4000
4100	1.5	2.5	4.0	5.5	6.5	8.0	9.5	11.0	12.0	13.5	15.0	16.0	17.5	19.0	20.0	21.5	23.0	24.5	25.5	27.0	28.5	30.0	4100
4200	1.5	3.0	4.0	5.5	7.0	8.5	9.5	11.0	12.5	14.0	15.0	16.5	18.0	19.5	20.5	22.0	23.5	25.0	26.0	27.5	29.0	30.5	4200
4300	1.5	3.0	4.5	5.5	7.0	8.5	10.0	11.5	12.5	14.0	15.5	17.0	18.5	20.0	21.0	22.5	24.0	25.5	27.0	28.5	29.5	31.0	4300
4400	1.5	3.0	4.5	6.0	7.0	8.5	10.0	11.5	13.0	14.5	16.0	17.5	19.0	20.0	21.5	23.0	24.5	26.0	27.5	29.0	30.5	32.0	4400
4500	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0	13.5	15.0	16.5	18.0	19.5	20.5	22.0	23.5	25.0	26.5	28.0	29.5	31.0	32.5	4500
4600	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0	13.5	15.0	16.5	18.0	19.5	21.0	22.5	24.0	25.5	27.0	28.5	30.5	32.0	33.5	4600
4700	1.5	3.0	4.5	6.0	7.5	9.5	10.5	12.5	14.0	15.5	17.0	18.5	20.0	21.5	23.0	24.5	26.0	27.5	29.5	31.0	32.5	34.0	4700
4800	1.5	3.0	4.5	6.5	8.0	9.5	11.0	12.5	14.0	16.0	17.5	19.0	20.5	22.0	23.5	25.0	27.0	28.5	30.0	31.5	33.0	35.0	4800
4900	1.5	3.0	5.0	6.5	8.0	9.5	11.5	13.0	14.5	16.0	17.5	19.5	21.0	22.5	24.0	25.5	27.5	29.0	30.5	32.5	34.0	35.5	4900
5000	1.5	3.5	5.0	6.5	8.0	10.0	11.5	13.0	15.0	16.5	18.0	19.5	21.5	23.0	24.5	26.5	28.0	29.5	31.5	33.0	34.5	36.0	5000
	.27	.29	.31	.33	.35	.37	.39	.41	.43	.45	.47	.49	.51	.53	.55	.57	.59	.61	.63	.65	.67	.69	

Neutralizing Table (Continued)

Pounds of Cream	PERCENT ACID IN CREAM .71	.73	.75	.77	.79	.81	.83	.85	.87	.89	.91	.93	.95	.97	.99	1.01	1.03	1.05	1.07	1.09	1.11	1.13	Pounds of Cream
100	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	100
200	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3.0	3.0	3.0	200
300	2.5	2.5	2.5	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.5	3.5	3.5	3.5	3.5	4.0	4.0	4.0	4.0	4.0	4.0	4.5	300
400	3.0	3.0	3.5	3.5	3.5	3.5	4.0	4.0	4.0	4.0	4.5	4.5	4.5	4.5	5.0	5.0	5.0	5.5	5.5	5.5	5.5	6.0	400
500	4.0	4.0	4.0	4.5	4.5	4.5	5.0	5.0	5.0	5.5	5.5	5.5	6.0	6.0	6.0	6.5	6.5	6.5	7.0	7.0	7.0	7.0	500
600	4.5	4.5	5.0	5.0	5.5	5.5	5.5	6.0	6.0	6.5	6.5	6.5	7.0	7.0	7.5	7.5	7.5	8.0	8.0	8.5	8.5	8.5	600
700	5.5	5.5	6.0	6.0	6.0	6.5	6.5	7.0	7.0	7.5	7.5	8.0	8.0	8.5	8.5	9.0	9.0	9.0	9.5	9.5	10.0	10.0	700
800	6.0	6.5	6.5	7.0	7.0	7.5	7.5	8.0	8.0	8.5	8.5	9.0	9.0	9.5	9.5	10.0	10.5	10.5	11.0	11.0	11.5	11.5	800
900	7.0	7.0	7.5	7.5	8.0	8.5	8.5	9.0	9.0	9.5	10.0	10.0	10.5	10.5	11.0	11.5	11.5	12.0	12.0	12.5	13.0	13.0	900
1000	7.5	8.0	8.0	8.5	9.0	9.0	9.5	10.0	10.0	10.5	11.0	11.0	11.5	12.0	12.0	12.5	13.0	13.0	13.5	14.0	14.0	14.5	1000
1100	8.5	8.5	9.0	9.5	10.0	10.0	10.5	11.0	11.0	11.5	12.0	12.5	12.5	13.0	13.5	14.0	14.0	14.5	15.0	15.0	15.5	16.0	1100
1200	9.0	9.5	10.0	10.5	10.5	11.0	11.5	12.0	12.0	12.5	13.0	13.5	14.0	14.0	14.5	15.0	15.5	16.0	16.0	16.5	17.0	17.5	1200
1300	10.0	10.5	10.5	11.0	11.5	12.0	12.5	13.0	13.5	13.5	14.0	14.5	15.0	15.5	16.0	16.5	16.5	17.0	17.5	18.0	18.5	19.0	1300
1400	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	20.0	20.5	1400
1500	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	17.5	18.5	19.0	19.0	20.0	20.5	20.5	21.0	21.5	1500
1600	12.0	12.5	13.0	13.5	14.0	14.5	15.0	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	1600
1700	13.0	13.5	14.0	14.5	15.0	15.5	16.0	17.0	17.5	18.0	18.5	19.0	19.5	20.0	20.5	21.5	22.0	22.5	23.0	23.5	24.0	24.5	1700
1800	13.5	14.0	15.0	15.5	16.0	16.5	17.0	18.0	18.5	19.0	19.5	20.0	20.5	21.5	22.0	22.5	23.0	23.5	24.5	25.0	25.5	26.0	1800
1900	14.5	15.0	15.5	16.5	17.0	17.5	18.0	19.0	19.5	20.0	20.5	21.5	22.0	22.5	23.0	24.0	24.5	25.0	25.5	26.0	27.0	27.5	1900
2000	15.0	16.0	16.5	17.0	18.0	18.5	19.0	19.5	20.5	21.0	22.0	22.5	23.0	23.5	24.5	25.0	25.5	26.5	27.0	27.5	28.5	29.0	2000
2100	16.0	16.5	17.0	18.0	18.5	19.5	20.0	20.5	21.5	22.0	23.0	23.5	24.0	25.0	25.5	26.5	27.0	27.5	28.5	29.0	29.5	30.5	2100
2200	16.5	17.5	18.0	19.0	19.5	20.0	21.0	21.5	22.5	23.0	24.0	24.5	25.5	26.0	27.0	27.5	28.0	29.0	29.5	30.5	31.0	32.0	2200
2300	17.5	18.0	19.0	19.5	20.5	21.0	22.0	22.5	23.5	24.0	25.0	26.0	26.5	27.0	28.0	29.0	29.5	30.5	31.0	31.5	32.5	33.5	2300
2400	18.0	19.0	19.5	20.5	21.5	22.0	23.0	23.5	24.5	25.0	26.0	27.0	27.5	28.5	29.5	30.0	30.5	31.5	32.5	33.0	34.0	35.0	2400
2500	19.0	20.0	20.5	21.5	22.0	23.0	24.0	24.5	25.5	26.5	27.0	28.0	29.0	29.5	30.5	31.5	32.0	33.0	34.0	34.5	35.5	36.0	2500
2600	19.5	20.5	21.5	22.0	23.0	24.0	25.0	25.5	26.5	27.5	28.5	29.0	30.0	30.5	31.5	32.5	33.5	34.0	35.0	36.0	37.0	37.5	2600
2700	20.5	21.5	22.0	23.0	24.0	25.0	26.0	26.5	27.5	28.5	29.5	30.0	31.0	32.0	33.0	34.0	34.5	35.5	36.5	37.5	38.0	39.0	2700
2800	21.0	22.0	23.0	24.0	25.0	26.0	26.5	27.5	28.5	29.5	30.5	31.5	32.0	33.0	34.0	35.0	36.0	37.0	38.0	38.5	39.5	40.5	2800
2900	22.0	23.0	24.0	25.0	26.0	26.5	27.5	28.5	29.5	30.5	31.5	32.5	33.5	34.0	35.5	36.5	37.0	38.0	39.0	40.0	41.0	42.0	2900
3000	22.5	23.5	24.5	25.5	26.5	27.5	28.5	29.5	30.5	31.5	32.5	33.5	34.5	35.5	36.5	37.5	38.5	39.5	40.5	41.5	42.5	43.5	3000
3100	23.5	24.5	25.5	26.5	27.5	28.5	29.5	30.5	31.5	32.5	34.0	34.5	35.5	36.5	38.0	39.0	39.5	41.0	42.0	43.0	44.0	45.0	3100
3200	24.0	25.5	26.0	27.0	28.5	29.5	30.5	31.5	32.5	33.5	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0	44.0	45.0	46.5	3200
3300	25.0	26.0	27.0	28.0	29.5	30.5	31.5	32.5	33.5	34.5	36.0	37.0	38.0	39.0	40.0	41.5	42.5	43.5	44.5	45.5	46.5	48.0	3300
3400	25.5	27.0	28.0	29.0	30.5	31.5	32.5	33.5	34.5	35.5	37.0	38.0	39.0	40.0	41.5	42.5	43.5	45.0	46.0	47.0	48.0	49.5	3400
3500	26.5	27.5	28.5	30.0	31.0	32.0	33.5	34.5	35.5	37.0	38.0	39.0	40.5	41.5	42.5	44.0	45.0	46.0	47.5	48.5	49.5	50.5	3500
3600	27.0	28.5	29.5	30.5	32.0	33.0	34.5	35.5	36.5	38.0	39.0	40.5	41.5	42.5	44.0	45.0	46.0	47.5	48.5	49.5	51.0	52.0	3600
3700	28.0	29.0	30.5	31.5	33.0	34.0	35.5	36.5	37.5	39.0	40.5	41.5	42.5	43.5	45.0	46.5	47.5	48.5	50.0	51.0	52.5	53.5	3700
3800	29.0	30.0	31.0	32.5	34.0	35.0	36.0	37.5	39.0	40.0	41.5	42.5	43.5	45.0	46.5	47.5	48.5	50.0	51.5	52.5	53.5	55.0	3800
3900	29.5	31.0	32.0	33.0	34.5	36.0	37.0	38.5	40.0	41.0	42.5	43.5	45.0	46.0	47.5	49.0	50.0	51.5	52.5	54.0	55.0	56.5	3900
4000	30.0	31.5	33.0	34.0	35.5	37.0	38.0	39.5	41.0	42.0	43.5	45 0	46.0	47.0	49.0	50.0	51.0	52.5	54.0	55.0	56.5	58.0	4000
4100	31.0	32.5	33.5	35.0	36.5	37.5	39.0	40.5	42.0	43.0	44.5	46.0	47.0	48.5	50.0	51.5	52.5	54.0	55.5	56.5	58.0	59.5	4100
4200	32.0	33.0	34.5	36.0	37.5	38.5	40.0	41.5	43.0	44.0	46.0	47.0	48.5	49.5	51.0	52.5	54.0	55.5	56.5	58.0	59.5	61.0	4200
4300	32.5	34.0	35.5	37.0	38.5	39.5	41.0	42.5	44.0	45.0	47.0	48.0	49.5	51.0	52.5	54.0	55.0	56.5	58.0	59.5	60.5	62.5	4300
4400	33.0	35.0	36.0	37.5	39.0	40.5	42.0	43.5	45.0	46.0	48.0	49.5	50.5	52.0	53.0	55.0	56.0	58.0	59.5	60.5	62.0	64.0	4400
4500	34.0	35.5	37.0	38.5	40.0	41.5	43.0	44.5	46.0	47.5	49.0	50.5	52.0	53.0	55.0	56.5	57.5	59.5	61.0	62.0	63.5	65.0	4500
4600	35.0	36.5	38.0	39.5	41.0	42.5	44.0	45.5	47.0	48.5	50.0	51.5	53.0	54.5	56.0	57.5	59.0	60.5	62.0	63.5	65.0	66.5	4600
4700	35.5	37.0	38.5	40.0	42.0	43.0	45.0	46.5	48.0	49.5	51.0	52.5	54.0	55.5	57.5	59.0	60.0	62.0	63.5	65.0	66.5	68.0	4700
4800	36.5	38.0	39.5	41.0	42.5	44.0	45.5	47.5	49.0	50.5	52.5	53.5	55.0	56.5	58.5	60.0	61.5	63.0	65.0	66.0	68.0	69.5	4800
4900	37.0	38.5	40.5	42.0	43.5	45.0	46.5	48.5	50.0	51.5	53.5	55.0	56.5	58.0	60.0	61.5	62.5	64.5	66.0	67.5	69.5	71.0	4900
5000	38.0	40.0	41.0	43.0	44.5	46.0	47.5	49.5	51.0	52.5	54.5	56.0	57.5	59.0	61.0	62.5	64.0	66.0	67.5	69.0	70.5	72.5	5000
	.71	.73	.75	.77	.79	.81	.83	.85	.87	.89	.91	.93	.95	.97	.99	1.01	1.03	1.05	1.07	1.09	1.11	1.13	

CHAPTER XI

PASTEURIZATION

The process of pasteurization derives its name from the eminent French Scientist, Louis Pasteur (1822-1895). It was Pasteur's discovery that fermentation is the result of the activity of living germs which do not happen spontaneously, but which have parents and which, themselves, reproduce and bring forth new generations. Pasteur further discovered that bacteria can be destroyed by heat below the boiling point of water (at a temperature as low as 140° F.), and that by proper application of heat it is possible to destroy the objectionable germ life, and to control the growth of those species that are desired.

During the years 1860-1864 Pasteur was called upon by the French Government to investigate the cause and prevention of a wine disease (abnormal fermentation of the wine) that caused wide-spread economic loss to the wine interests in France. He successfully demonstrated that, by heating the wine to a temperature range of 50 to 60° C. (122 to 140° F.) and holding it at this temperature for a short time, the objectionable fermentation could be prevented.

While the earliest efforts of preserving milk by heat treatment predate the studies of Pasteur, the true cause of spoilage was not known. It was Pasteur's discovery of the cause of fermentations and of dependable methods for their control, that brought forth the process known as pasteurization. Its application in the dairy industry has proved a lasting blessing to the consumer of dairy products and of incalculable economic benefit to the industry itself.

According to Wilster[46] pasteurization of cream for butter making became common in Denmark shortly after 1890. In 1898, when the process became compulsory, practically all the creameries were already using it. The law required the cream to be flash heated to a temperature of 85° C. (185° F.). This temperature was reduced in 1904 to 80° C. (176° F.). Today a temperature range of 90 to 95° C. (194 to 203° F.) is said to be commonly used, and in many instances repasteurization is practiced, the whole milk being pasteurized prior to separation.

followed by pasteurization of the cream from the separator.

In the United States pasteurization of cream for butter manufacture took permanent foothold during the first decade of this century, although the process had been introduced in a number of creameries prior to 1900. While accurate statistical records are lacking, it appears safe to state that the great bulk of all American creamery butter is now made from pasteurized cream.

Definition.—As applied to butter making, pasteurization may be defined as the process of heating milk, or cream, or other fluid milk product, to a temperature sufficiently high and for a

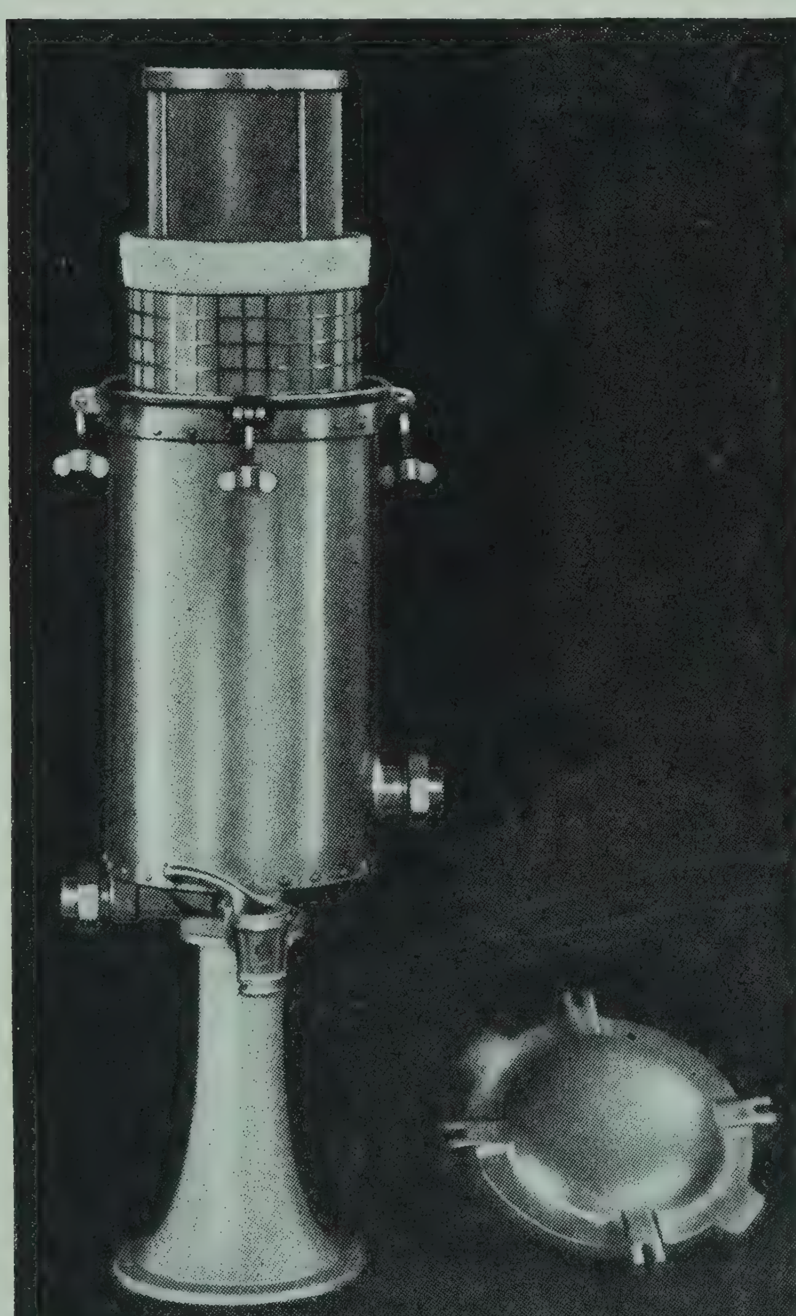


Fig. 38. Cream pressure strainer used between forewarmer and pasteurizer.
Courtesy of Cherry-Burrell Corporation

duration of time sufficiently long, to insure the destruction of the germs and viruses of milk-borne diseases, and of the great majority of all other non-sporing micro-organisms and ferments

present, followed by prompt cooling to the ripening or churning temperature.

The Temperature-Time Factor in Pasteurization.—Efforts to insure maximum germ destruction consistent with minimum heat flavor, have covered trials of a wide range of temperature-time combinations, and have led to the establishment of the following recognized methods of heat treatment:

1. Flash pasteurization by the continuous process, in which the cream flows through the pasteurizer in a continuous stream, is heated to the desired temperature (180° F. or above), followed by immediate flash cooling.

2. Vat or holding pasteurization, in which the cream is heated by the batch system, usually to 145-160° F., then held at that temperature for 30 minutes, followed by batch cooling.

3. Combination of flash heating and batch holding and cooling. In this procedure the cream is usually heated by the continuous method to 160-170° F., then held at that temperature in a vat for 20 to 30 minutes, followed by batch cooling.

On the European continent and in the great butter exporting countries of the southern hemisphere, preference is given to flash pasteurization at temperatures well above 180° F. (near 200° F.). In the United States and Canada vat pasteurization at 145 to 160° F. for 30 minutes is a common practice, especially among creameries of moderate volume and located in sections where sour cream predominates, while butter factories with large volume generally use flash pasteurization. The general trend lies in the direction of pasteurization at the higher temperatures.

FLASH OR CONTINUOUS PASTEURIZATION

Types of Flash Pasteurizers.—The various types of flash pasteurizers used in butter manufacture are conveniently grouped as follows:

1. Pasteurizers with metal heating surface.
2. Steam-injection pasteurizers.
3. Vacuum pasteurizers.
4. Electric pasteurizers.

1. Pasteurizers with Metal Heating Surface.—Pasteurizers in which the cream is heated by contact with metal heating

surfaces have been in use in the creamery from the very beginning of pasteurization, and they are today the most universally used type of machines. To this group belong the Danish and the Cherry-Jensen type of pasteurizers, the Jensen pasteurizer unit, the Farrington Disc Continuous pasteurizer, and the plate heat exchanger.

The Danish and the Cherry-Jensen pasteurizers consist of a stationary, steam-jacketed drum with revolving wing agitator. The cream enters at or near the bottom, passes over the heating

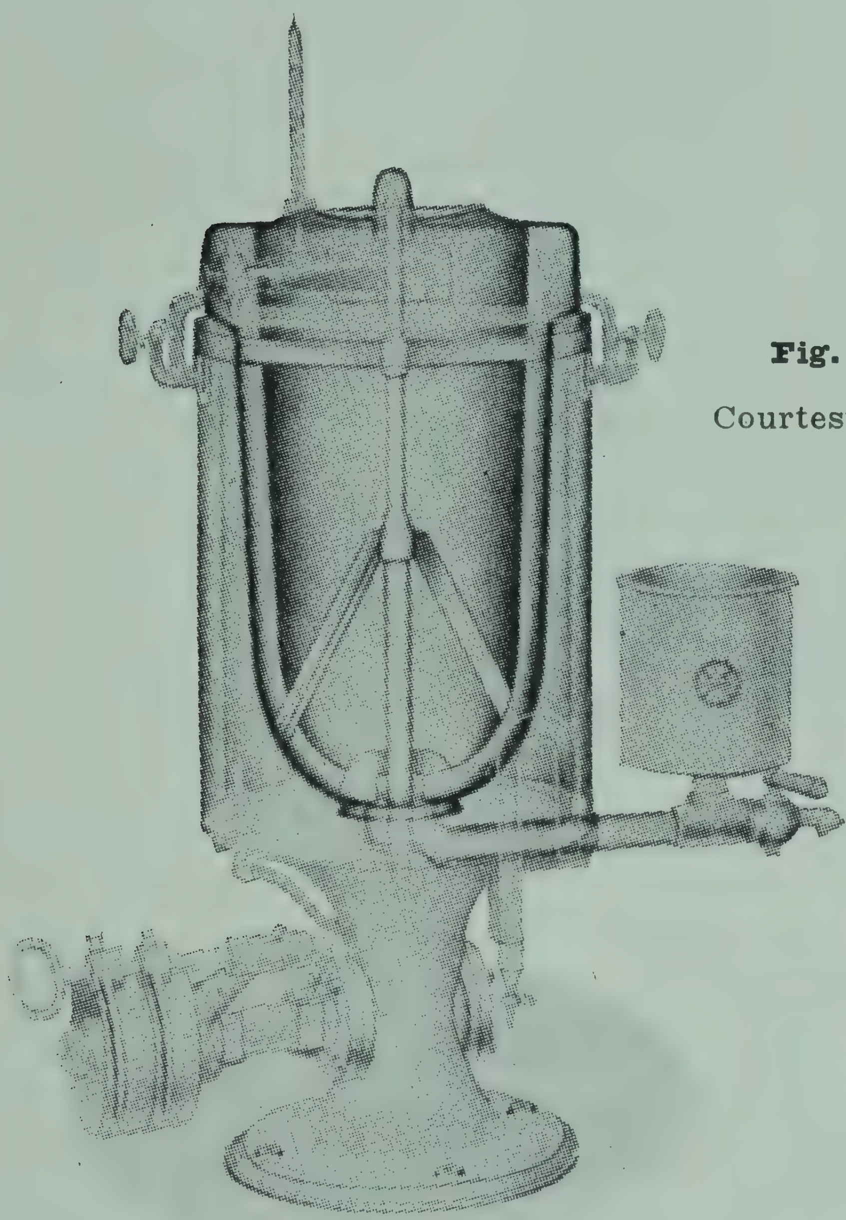


Fig. 39. Silkeborg flash pasteurizer
Courtesy of Silkeborg Maskinfabrik

surface with considerable velocity due to the rapidly revolving agitator, and discharges from the top of the machine under sufficient pressure to lift it to any reasonable elevation, such as over the surface cooler or regenerator.

The Jensen pasteurizer unit consists of a drum heater, regenerator, and drum cooler. The cream entering the heater passes in a thin layer between two heated, nested drums, of which the inner drum is revolving. From the heater it flows upward

through the regenerator, being precooled by the cold raw cream that flows down over the outside of the regenerator on its way to the heater. From the regenerator the pasteurized cream en-

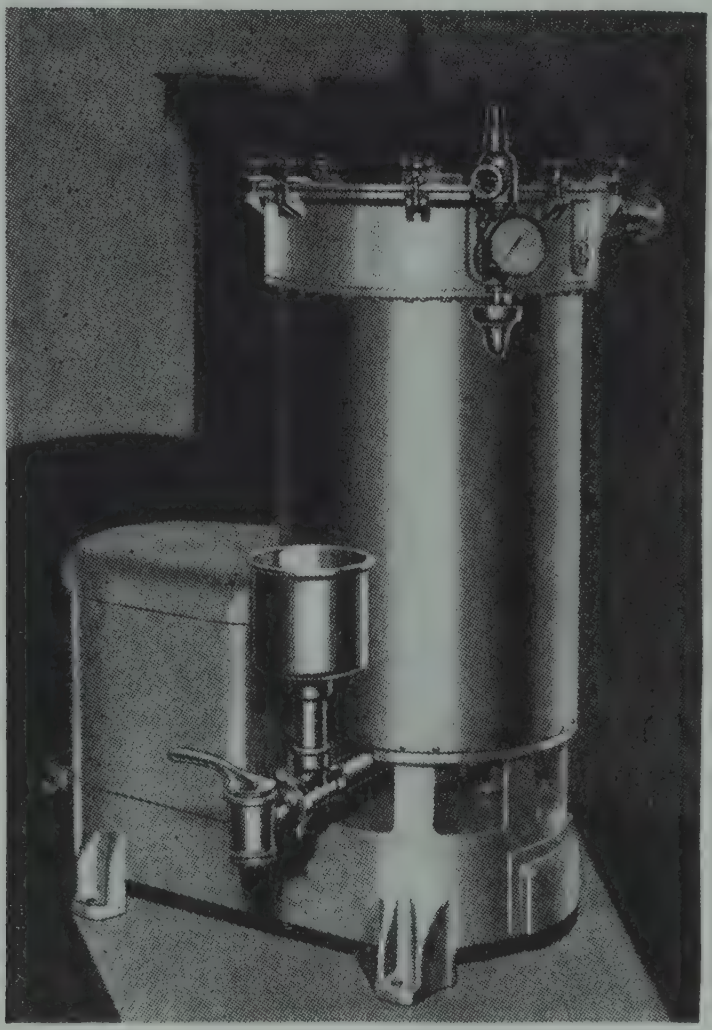


Fig. 40. Cherry-Jensen flash pasteurizer
Courtesy of Cherry-Burrell Corporation

ters the cooler, which consists of two water-cooled, nested drums with the inner drum revolving. The flow of cream is expedited by an impeller attachment at the intake end of the revolving drum of each, the pasteurizer and the cooler.

The Farrington Disc Continuous pasteurizer consists of one or more compartments, each equipped with a battery of revolving, steam-heated discs, which heat the cream while it is flowing through the compartments. The pasteurizer may also contain similar compartments for cooling.

The Plate Heat Exchanger is made up of a series of thin metal plates, that are held tightly together in a press. The plates are grooved either on one side or on both sides; in the latter case the grooved plates alternate with flat plates. The grooves serve as canals through which the cream flows. This pasteurizer is built for high temperature flash heating, or limited retarding or holding pasteurization, with or without regenerative units and cooling units. The heating medium (hot water) and the

cold water and brine travel in counter-current to the flow of cream.

The depth of the grooves in the plates determines the thickness of the layer of cream between the plates. The grooves are shallow and of even depth. They, therefore, insure a uniformly thin layer of cream. This fact, together with the thinness of the metal plates, and the high velocity of the heating medium insures rapid and uniform heat exchange and makes possible the use of hot water at a temperature only a few degrees higher than the desired pasteurizing temperature of the cream. It also practically eliminates the tendency of scorching and of cooked flavor. The plate heat exchanger is flexible as to capacity. For increasing its capacity, more sections of plates are added.

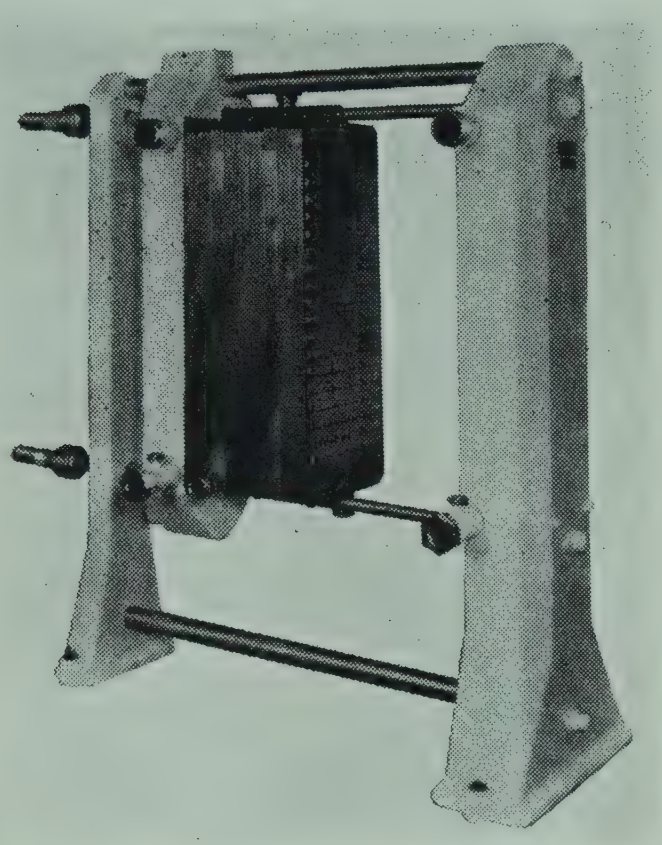


Fig. 41. York plate heat exchanger

2. **Steam-Injection Pasteurizers.**—The cream is heated by jets of "live" steam, eliminating the necessity of heat exchange through metal heating surfaces, and utilizing all of the latent heat of the steam. The steam jets used in different installations are of diverse types, such as simple steam nozzles, steam rosettes, sections of pipes perforated with needle jets of varying size and bored at different angles, the Venturi constricted tube injector, etc. The principle of direct-steam pasteurization makes possible heating under pressure and to temperatures above the boiling point, without objectionable heat damage to the flavor of the cream. It is used extensively in connection with treatment for removal of objectionable flavors, as explained in Chapter XII.

As applied to standard flash pasteurization at 180° F. or above, the Cooney jet pasteurizer is a representative of this type. It consists in the main of two sections of 2″ sanitary

cream pipe about 36″ long, each carrying in its interior a smaller pipe perforated with needle jets bored at an angle of about 30° concurrently with the cream flow, and is equipped with steam connections, sanitary fittings and thermometer. In the first heating section the cream is heated to approximately 160 to 170° F. and in the second section to the final pasteurizing temperature (180° F. or above). For attaining temperatures above the boiling point, a suitable cream pressure control valve is installed at the end of the second jet section, whereby the cream flow may be choked back to attain the desired pressure and temperature.

In order to accomplish high germ-killing efficiency by steam injection pasteurization, it is necessary to insure vigorous impingement of steam upon cream and intense and thorough intermingling of the particles of steam and cream. Experiments by Hunziker and Cordes[1] with the Cooney pasteurizer, heating to 185° F., showed the total bacteria count of the pasteurized cream to run well over 100,000, averaging about 140,000, while the ordinary flash pasteurizer with metal heating surface, gave total bacteria counts well under 10,000, usually about 2,000 to 3,000. These results suggest that the mere injection of steam into the cream through needle jets concurrently, as provided by the Cooney system, does not necessarily mean that the cream itself has been heated to the temperature shown on the recording chart, but that, due to inadequate impingement and incomplete intermingling, free steam may reach the thermometer bulb, causing the temperature readings to be erroneously higher than the actual temperature of the cream. Extension of the cream line between pasteurizer and cooler assists in minimizing or eliminating this discrepancy.

3. **Vacuum Pasteurizers.**—Other steam injection pasteurizer units are also equipped with vacuum chambers, giving the cream a combination of heating with "live steam" and vacuum treatment. The majority of these units provide highly efficient heat treatment that insures dependably high germ destruction. These steam injection-vacuum pasteurizers are capable, in addition, of removing objectionable flavors and odors, such as weed and feed flavors, and certain other readily volatilizable flavors. They are discussed in detail in Chapter XII on "Treatment of Cream for Removal of Objectionable Flavors and Odors."

The steam supply of the steam injection pasteurizer should be pure and dry to protect the cream from boiler impurities and from excessive dilution. At best, the dilution by this system, due to steam condensate, is sufficient to lower the cream test about three per cent. It is advisable, therefore, to install an efficient steam purifier and suitable steam trap in the steam line approaching the pasteurizer. For "Steam Purifiers" see Chapter III.

4. Electric Pasteurizers.—These machines are equipped with electrodes, and the electric current that passes through the liquid to be pasteurized constitutes the pasteurizing element. The electric current thus utilizes the fluid milk product as the medium of resistance, and is thereby transformed into heat.

Representative electric pasteurizers that have reached commercially successful application are the Electropasteur of Aten and Straub, Holland, described in detail by McDowall[2], and the Electropure pasteurizer of the Electropure Sales Corporation, Pittsburgh, U.S.A. The Aten and Straub machine is a modification of an earlier type, originally developed in 1911 by Beattie and Lewis, England. In the European machine the milk is heated in a lethal tube with high terminal voltages. The current passes along the stream of milk. In the Electropure pasteurizer ordinary voltages (230 A.C., 60 cycles) are used, and the electric current passes across the flow of milk.

The earliest conceptions of the action of electrical pasteurization were that the electric current had a direct germicidal effect. Later investigations tended to discredit this theory, suggesting that the germ-killing effect of electric pasteurization was limited exclusively to the lethal effect of the heat generated. More recent findings, relative to the destruction of bacterial spores, by Gelpi and Devereux[3], and also by Tracy[4], however, indicate that the alternating current of 60 cycles, does have a lethal effect, additional to that of the heat generated.

Experimental results and commercial experience have conclusively demonstrated that the flavor of milk is not damaged and the keeping quality is improved by the Electropure process of pasteurization. The process has the additional advantages that it eliminates metal heating surfaces and provides dependable automatic heat control.

The process has the disadvantage of the possibility of sudden interruption in the case of temporary absence of electric

current. Furthermore, in general, the conversion of fuel into electricity and its transformation into heat, tends to increase the cost of pasteurization by electricity over that by steam, with the possible exception of localities where unusually cheap electric current is available, such as may be obtained in regions blessed with an abundant supply of low-cost hydro-electric power.

There appears to be a complete absence of any published evidence that electric pasteurization has ever been used for cream intended for butter manufacture. Electric pasteurization in the creamery lies within the range of possibilities, particularly in the case of creameries receiving whole milk. For cream its suitability appears less promising, on account of the probable tendency of fouling the electrodes.

Capacity of Flash Pasteurizer.—The capacity of the pasteurizer necessarily depends on the size and arrangement of the heating surface, the velocity with which the cream passes over the heating surface, the kind and temperature of heating medium, the initial temperature and condition of the cream, and the pasteurizing temperature desired.

The flash pasteurizer is a piece of creamery equipment of which a great deal is expected. It must heat large volumes of cream, by momentary exposure, to a temperature sufficiently high to destroy all germs of milk-borne diseases and it must accomplish a high total germ-killing efficiency. It must do this without scorching that would injure the flavor of the resulting butter. Such performance is possible only by operation that does not "crowd" the machine.

At best, the listed capacity of most pasteurizers is overrated from the standpoint of average conditions prevailing in commercial operation. Adding to this the human factor with its almost inevitable tendency to force the machine beyond its rated capacity, efficiency of pasteurization is not infrequently jeopardized. The most effective safeguard of proper pasteurization, therefore, must lie in making these machines as nearly "fool-proof" as possible. Commercial experience has yielded conclusive proof of the advantages of operating two flash machines in tandem formation, "stepping up" the heat in two installments, and of providing automatic temperature control for the second pasteurizer. In addition, the cream exit of the flash

pasteurizer should be equipped with a by-pass, whereby all cream may be returned to the first machine, or to the fore-warmer, until the outflowing cream has reached the full, desired pasteurizing temperature. The uniformity of results is further enhanced, and fuel and refrigeration economized, by preheating the cream in the forewarmer to a uniform temperature and by the use of a regenerative heater-cooler. Such a combination unit of flash pasteurizer provides a highly effective means of insuring maximum pasteurizing efficiency, consistent with reasonable protection against injury to quality, without sacrificing speed of operation and capacity of machine.

TEMPERATURE CONTROL IN FLASH PASTEURIZATION

Importance of Efficient Control.—Efficient flash pasteurization is possible only when all the cream that passes through the pasteurizing unit is heated to full pasteurizing temperature. The accomplishment of this requires constant regulation of the temperature. This may be done by hand operation, the operator controlling the rise and fall of the temperature of the cream by regulating the cream flow and the steam supply valves. Temperature record charts, however, show conclusively that the efficiency of hand control is uncertain and the line on the temperature chart often very irregular, indicating that some of the cream escaped from the pasteurizer at temperatures widely deviating from the standard temperature desired. These fluctuations are usually greatest where one pasteurizer only is used. But even where operating two pasteurizers, connected in tandem formation, temperature irregularities are too great to insure uniform heating to the desired temperature, when depending on regulation by hand.

Automatic Temperature Controlling Devices. — Uniform heating of all the cream to the desired temperature is made possible by the use of a properly installed and accurately functioning system of automatic temperature control. Such a system involves such essential features as: air compressor, pressure regulator, recording temperature controller, and proper installation of cream lines and steam lines. A suitable installation of temperature control is graphically illustrated in Figure 42, and described in detail below:

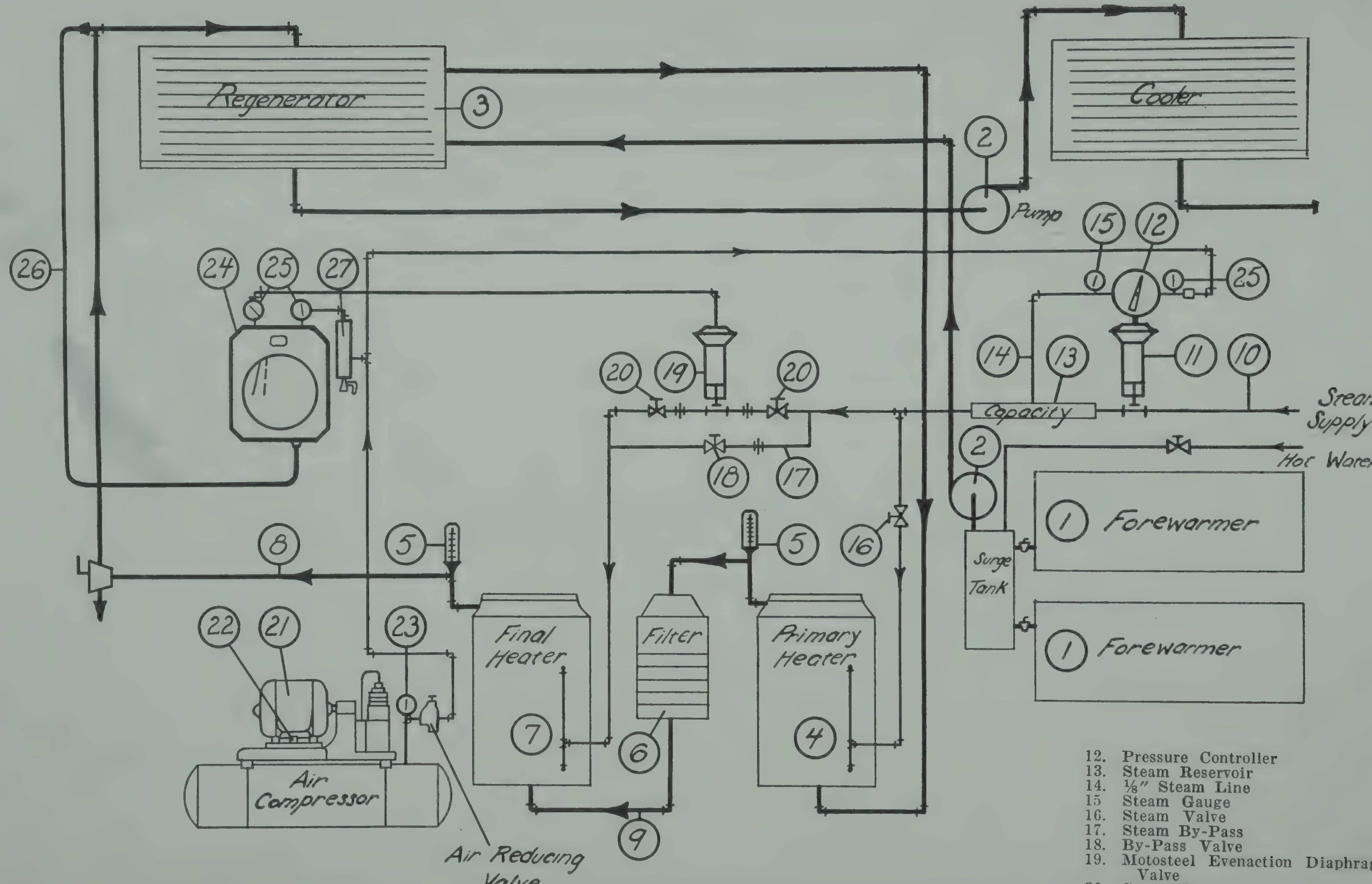


Fig. 42. Temperature control flow-sheet for flash pasteurization

Courtesy of Taylor Instrument Companies

1. Forewarmer
2. Cream Pump
3. Regenerator
4. First Pasteurizer
5. Industrial Thermometers
6. Filter
7. Second Pasteurizer
8. Cream Line to Regenerator
9. Cream Line to Second Pasteurizer
10. Steam Line from Boiler
11. Motosteel Evenaction Diaphragm Valve
12. Pressure Controller
13. Steam Reservoir
14. ⅛" Steam Line
15. Steam Gauge
16. Steam Valve
17. Steam By-Pass
18. By-Pass Valve
19. Motosteel Evenaction Diaphragm Valve
20. Steam Valves
21. Air Compressor
22. Pop-Off Valve
23. Air Pressure Gauge
24. Recording Temperature Controller
25. Air Gauge
26. Capillary Tube
27. Air Strainer

Cream Line. — The cream is pumped by pump (2) from forewarmers (1) to regenerator (3), where it is preheated by the pasteurized cream from cream line (8). From the regenerator the preheated cream flows to the first pasteurizer (4), which discharges it through filter (6) into the second pasteurizer (7). From here it passes through cream line (8) back to regenerator (3) to give up heat to the raw cream, and then it flows to cooler (9).

A uniform and readily controlled continuous cream flow is essential, and heat control is facilitated by having the cream leave the forewarmers at a uniform temperature. The cream flow is regulated by a valve for each forewarmer. The valves should be opened the same each time, so as to insure a uniform flow of cream to the pasteurizers.

The cream must pass in an unbroken flow through direct connections from regenerator (3) to first pasteurizer (4) and from there to the second pasteurizer (7). Open receiving cups furnished with the pasteurizers must, therefore, he displaced by direct pipe connections.

In the first pasteurizer (4) the cream is heated to about 150 to 160° F., and in the second pasteurizer (7) to the exact pasteurizing temperature desired (180° F. or above). The temperature in the first pasteurizer (4) need not be controlled to an exact point, since this is taken care of in the final heater (7).

The first cream passing through the pasteurizers is usually not heated to the full pasteurizing temperature. It should, therefore, be returned to the first pasteurizer (4). This is conveniently done by the installation of a by-pass (not shown in drawing). The by-passing should be continued until the cream leaving the second pasteurizer (7) registers 180° F. or over.

Steam Line.—The steam (10) runs from boiler to the two pasteurizers (4 and 7). For the best results the boiler steam pressure must be carried between 60 and 100 pounds. At less than 60 pounds boiler pressure the steam supply is not sufficient. For higher boiler pressure the steam line should be equipped with a reducing valve, set to reduce the pressure to about 90 pounds.

In the steam line (10) is installed a diaphragm valve (11). This valve should be large enough to supply sufficient steam to both pasteurizers and still not too large, causing a wide tem-

perature range. It regulates the steam pressure for both pasteurizers. It is operated by pressure regulator (12), which should be set to regulate the pressure at a minimum. This is usually about 40 pounds. This is the pressure immediately available to both pasteurizers.

On the pasteurizer-side of the diaphragm valve (11) is installed a steam reservoir (13). This consists of a three-foot section of 2½ inch pipe in the steam line. It is connected with the pressure regulator by a ⅛ inch pipe (14), equipped with steam pressure gauge (15). It acts as a reservoir to provide uniform pressure in case of sudden demands of steam.

The steam lines to the pasteurizers are ¾ inch pipes. The line to the first pasteurizer (4) is equipped with an ordinary valve (16). This valve is operated by hand to regulate the temperature to about 150 to 160° F.

The steam line leading to the second pasteurizer (7) carries steam by-pass (17) with valve (18), diaphragm valve (19), and ordinary valves (20) in the steam line to and from diaphragm valve (19). This diaphragm valve should be placed in the steam line as close to the second pasteurizer (7) as possible. The steam must enter the valve through the end marked "Inlet." The steam of the diaphragm valve must move freely. Stuffing box nut should not be screwed down too tightly since this will cause the stem to bind.

Valves (20) are ordinary valves. They should be left wide open. Their only purpose is to permit continuation of operation in case diaphragm valve (19) should fail to function properly, and requires inspection and repair. In such case valves (20) are closed and the steam supply to pasteurizer (7) is regulated manually by by-pass valve (18).

Air Compressor.—Compressed air is needed to operate diaphragm valves (11) and (19). This is supplied by air compressor (21). The air compressor consists of a pump with air chamber. The air chamber is equipped with pop-off valve (22) and air gauge (23). Pop-off valve (22) should be so set as to operate at 25 pounds air gauge pressure.

The compressed air goes from air compressor (21) direct to steam pressure regulator (12) and to recording temperature controller (24). The steam pressure regulator (12) discharges it to diaphragm valve (11) and the recording temperature con-

troller (24) to diaphragm valve (19). All air lines are of seamless ¼ inch copper tubing.

Before connecting them, the air lines should be blown out. Before operation each day the blow-off cock (22) on air compressor tank should be opened after starting air compressor (21), to eliminate oil, dirt, and water that may have collected. Proper functioning of the air compressor demands running it at the proper speed, as indicated by the manufacturer, and adequate lubrication is essential. The air compressor should be stopped when not in use.

Recording Temperature Controller.—The purpose of the recording temperature controller (24) is to control the volume of steam of the second pasteurizer (7), so as to make possible uniform heating of all the cream to the desired pasteurizing temperature. It is connected with air compressor (21) and diaphragm valve (19). It is advisable to install an air strainer (27) in the ¼ inch air line between compressor (21) and recording temperature controller (24). This strainer should be blown out daily. The recording temperature controller (24) also connects with the cream discharge line of pasteurizer (7) by flexible capillary tube (26). The bulb end of this tube should be inserted in the cream discharge line (8) of the second pasteurizer (7). Keep the temperature controller (24) and the flexible capillary tube (26) free from vibration and away from steam and brine pipes.

The mechanism of the temperature controller (24) Fig. 42, is shown in detail in Fig. 43. The temperature controller is adjusted to control at any temperature desired by turning the knurled knob on turning post (9) which moves the set pointer (62) to the desired temperature on the recording chart.

Motion of actuating coil (33) results from temperature changes around the thermometer bulb. With a rise in temperature there is an increase in vapor pressure of the highly volatile liquid in the tube system. When this pressure increases, the bulb and capillary are sufficiently rigid to be unaffected, but the actuating coil (33) uncoils. Likewise, with a decrease in temperature this coil acts in the reverse manner. The motion of the coil is transmitted through connecting link (15) to recording pen arm (61) which is pivoted at (4). This motion is further transmitted by link (8), which is mounted on the same

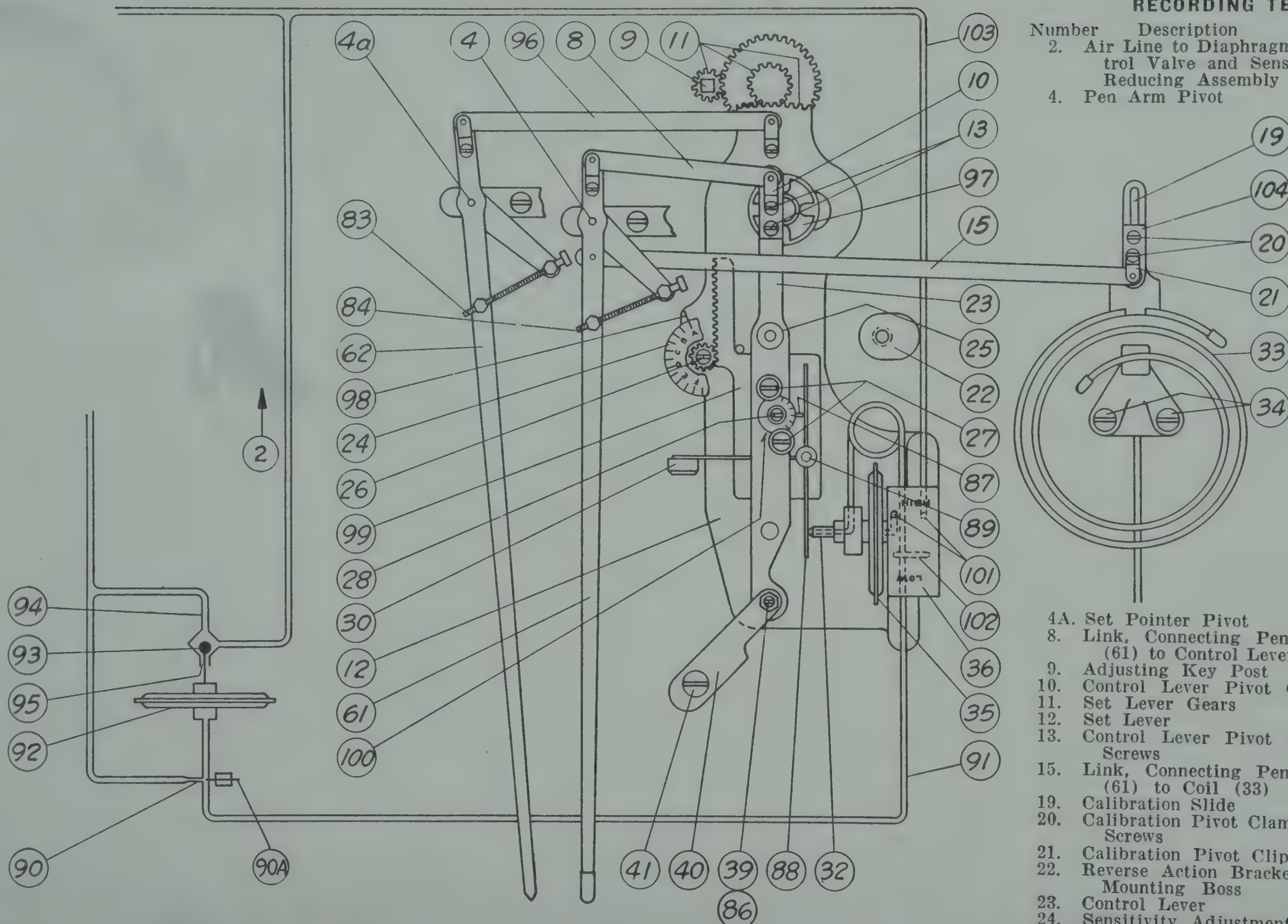


Fig. 43. **Mechanism of recording temperature controller**
Courtesy of Taylor Instrument Companies

RECORDING TEMPERATURE CONTROLLER

Number	Description
2.	Air Line to Diaphragm Control Valve and Sensitivity Reducing Assembly
4.	Pen Arm Pivot
4A.	Set Pointer Pivot
8.	Link, Connecting Pen Arm (61) to Control Lever (23)
9.	Adjusting Key Post
10.	Control Lever Pivot Clip
11.	Set Lever Gears
12.	Set Lever
13.	Control Lever Pivot Clamp Screws
15.	Link, Connecting Pen Arm (61) to Coil (33)
19.	Calibration Slide
20.	Calibration Pivot Clamp Screws
21.	Calibration Pivot Clip
22.	Reverse Action Bracket Mounting Boss
23.	Control Lever
24.	Sensitivity Adjustment Dial
25.	Pivot Staff for Reverse Action
26.	Sensitivity Adjustment Screw

Number	Description
27.	Actuating Stud Adjusting Dial Screws
28.	Actuating Stud Adjusting Screw
30.	Baffle counterweight
32.	Nozzle
33.	Actuating Coil, Tube System
34.	Actuating Coil Mounting Screws
35.	Sensitivity Reducing Bellows
36.	Sensitivity Change—Over Cover Plate
39.	Control Lever Pivot
40.	Control and Set Lever Bracket
41.	Control and Set Lever Bracket Mounting Screw
61.	Pen Arm
62.	Set Pointer
83.	Set Pointer Micrometer Adjustment
84.	Pen Arm Micrometer Adjustment
86.	Set Lever Pivot
87.	Baffle Actuating Stud
88.	Baffle
89.	Baffle Pivot
90.	Relay Air Valve Orifice
90A.	Orifice Cleaner
91.	Tube Connecting Nozzle with Relay Air Valve
92.	Relay Air Valve Bellows
93.	Relay Air Valve Ball
94.	Air Supply to Relay Air Valve
95	Exhaust Port, Relay Air Valve
96.	Set Pointer Connecting Link
97.	Set Lever Friction Washer
98.	Reference Mark for Red Sensitivity Adjustment Dial
99.	Sliding Base Plate with Baffle Assembly
100.	Black Dial for Adjusting Sensitivity Compensating Pin
101.	Ports in Nozzle Block, Connected for Low Sensitivity
102.	Connecting Slot in Coverplate for Nozzle
103.	Tube from Relay Air Valve Output Line to Sensitivity Reducing Bellows
104.	Calibration Take-Off Bearing Plate

shaft as pen arm (61) and is also pivoted at (4) to lever (23), which is pivoted at (39) to actuating stud (87), which is carried on the underside of lever (23).

Therefore, if the temperature of the cream in pasteurizer (7, Fig. 42) rises, the internal pressure in the tube system increases and coil (33, Fig. 43) uncoils. This motion is transmitted by the linkage to lever (23). Actuating stud (87) on lever (23) moves the baffle (88), which is pivoted at (89) away from nozzle (32). Air then escapes through the nozzles and the pressure in line (91) drops, deflating bellows (92) and allowing ball (93) to drop and open port (94). Air pressure is then applied to the diaphragm valve through line (2) and the valve closes, reducing the amount of steam being admitted, and the temperature will start to drop. When the temperature drops the action is reversed to allow more steam to enter the pasteurizer.

By adjusting the temperature change necessary to move the diaphragm valve from fully open to fully closed, it is possible for the controller to keep the valve in one position after the cream has come up to the desired temperature, and allow just the correct amount of steam to maintain that temperature without variation.

The relation between temperature change and valve movement is spoken of as "sensitivity." When the temperature change necessary to move the valve a full stroke is small, the sensitivity is termed "high," and when the temperature change necessary is large, the sensitivity is "low." The sensitivity of control is adjusted to any desired value by turning the red dial (24) of the sensitivity adjuster from "A," the position of highest sensitivity to "L," the position of lowest sensitivity. With the instrument in "A" sensitivity, that is, with "A" on dial (24) opposite the scribed mark (98), the lower end of baffle (88) will have maximum movement for a minimum of movement of actuating stud (87). Lowering the unit sensitivity by turning dial (24) from "A" successively through various positions down to "L," lowers sliding plate (99), which brings baffle pivot (89) closer to nozzle (32) and farther away from actuating stud (87). This means a greater stud movement, and consequently a greater temperature change is necessary to move the baffle with respect to its contact point with nozzle (32).

The sensitivity of the instrument should be properly adjusted if optimum results are to be obtained. If the sensitivity setting is too high, "hunting" will result. "Hunting" is the variation of temperature above and below the control point, caused by opening the steam valve too much. This causes the cream temperature to rise more than the desired amount. Too low sensitivities cause an unnecessary deviation from the control point because the diaphragm valve opens but a small amount for a large temperature change. When the sensitivity is properly adjusted, the diaphragm valve will throttle and maintain the temperature within narrow limits.

Recording Thermometer.—The recording temperature controller also functions as temperature recorder. The purpose of the recording thermometer is to make a permanent record of the temperature to which the cream is heated in the second pasteurizer (7, Fig. 42). The recording element consists of a flexible mercury tube (26) with a bulb which enters the cream outlet line of pasteurizer (7), and terminates at its other end in the controller case (24), in which the temperature is recorded on a slowly revolving chart by an ink-fed pen.

The recording thermometer should be checked for accuracy at frequent intervals (weekly). This is readily done by the use of an accurate test thermometer. The bulbs of both thermometers are immersed in a pail of water at the desired pasteurizing temperature (180° F. or over). The water is stirred constantly to make sure that both bulbs are subjected to the same temperature. The temperature indicated on the recording chart should coincide with the temperature shown on the check thermometer.

For correcting the recording thermometer, open the door of the case and adjust the micrometer screw (84, Fig. 43) on the pen arm until the correct temperature is indicated. When adjusted to correspond with the test thermometer, close the door to keep out moisture.

Although irregularities in the pasteurizing temperature as recorded on the temperature chart may be traced to improper sensitivity settings, it is advisable to check all other equipment and operation. Temperature variations may be caused by irregular steam supply; diaphragm valves may not be operating

freely; the air valve may not be operating properly because of dirt in orifice (90, Fig. 43). To clean the orifice merely push in the orifice cleaner (90A).

In order to insure proper functioning of the recording thermometer, avoid sharp bends of the connecting tubing (26, Fig. 42), and keep it away from steam pipes and brine pipes. Keep the recording pen clean and avoid its overflowing. Use non-corrosive ink. Always keep the instrument closed to protect the mechanism from dampness and dirt.

Pressure Controller.—The purpose of the pressure controller (12, Fig. 42) is to absorb fluctuations of the boiler pressure and thereby maintain a uniform steam pressure to the two pasteurizers. Its detailed mechanism is shown in Fig. 44.

The air supply enters the controller at (206) and is connected with diaphragm valve (11, Fig. 42). The steam supply

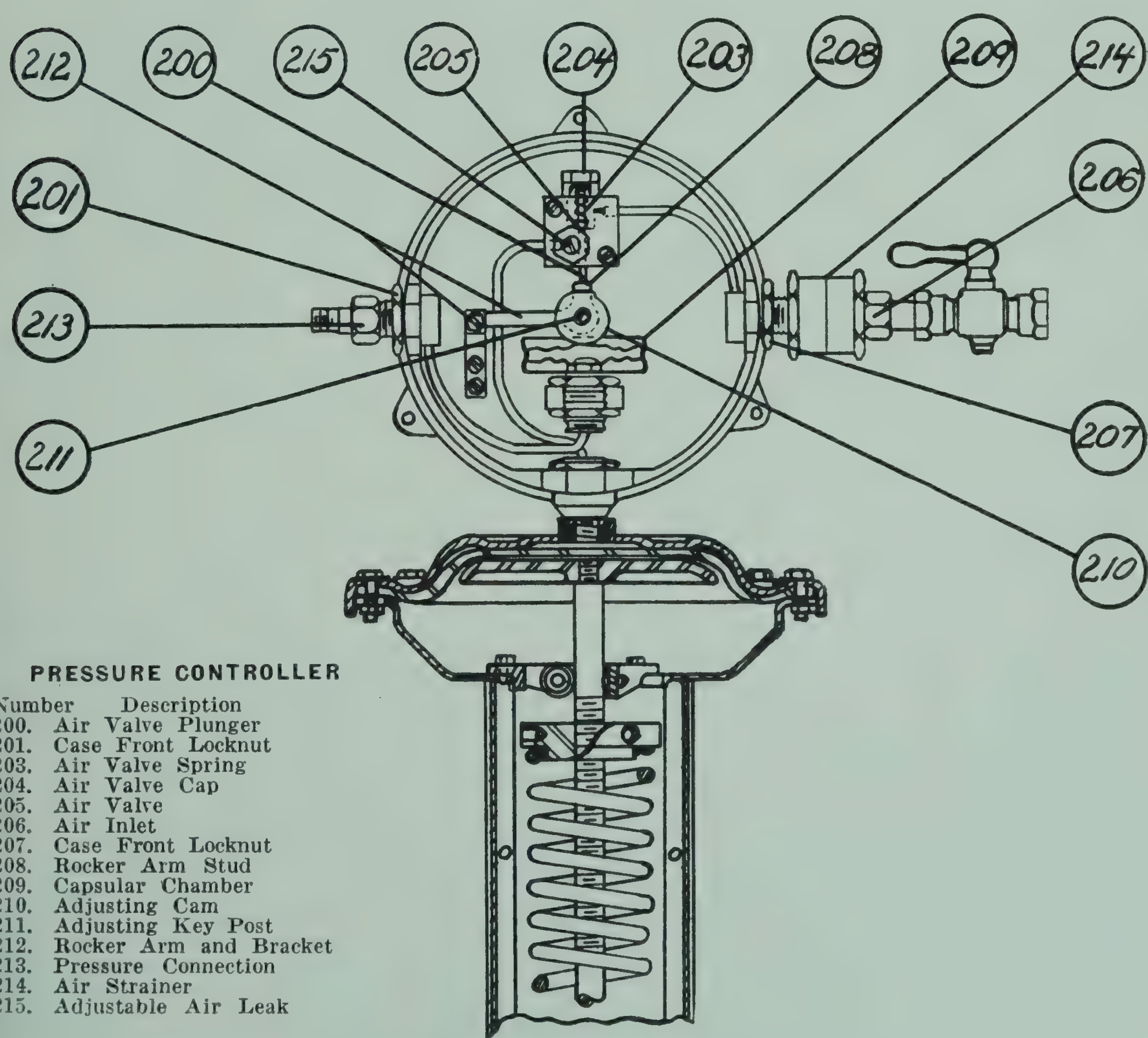


Fig. 44. Mechanism of pressure controller
Courtesy of Taylor Instrument Companies

enters the capsular chamber at (209) from steam reservoir (13, Fig. 42) through ¼ inch tubing (14, Fig. 42).

The pressure controller is adjusted to control at any pressure desired by changing the position of the adjusting cam (210). It should be set to regulate the steam pressure to the pasteurizers at a minimum pressure, usually about 40 pounds. Steam gauge (15, Fig. 42) shows the pressure. The pressure is increased by turning the adjusting post (211) to the right, and decreased by turning it to the left. If the steam pressure in the line to the pasteurizers drops below the minimum pressure, capsular chamber (209) in the pressure controller contracts. This closes air valve (205), releases the air pressure from diaphragm valve (11, Fig. 42) and opens the diaphragm valve, allowing more steam to go to the pasteurizers. If the steam pressure to the pasteurizers rises above the minimum pressure, the capsular chamber expands. This opens the air valve and the air pressure partly closes the diaphragm valve, cutting down the steam pressure to the pasteurizers.

The proper adjustment of the pressure controller by means of cam (210) and air leak (215) thus maintains a constant and uniform steam supply to the pasteurizers. In order for the controller to function satisfactorily, the boiler steam pressure should be reasonably uniform, it should not drop below 60 pounds; leaks in air valve (205) should be avoided by keeping it clean; the diaphragm valve should operate freely; and the steam gauge should be sufficiently accurate to indicate the exact steam pressure to pasteurizers.

COOLING THE FLASH-PASTEURIZED CREAM

Regenerative Heater-Coolers.—These heater-coolers operate on the principle of reciprocating heat exchangers between the hot outgoing and the cold incoming cream. They are in reality preheaters and precoolers, since they neither heat nor cool to the desired final temperature. They constitute a combination of intra-tube heater and surface cooler, the hot cream flowing up through the inside of the pipe unit and the cold cream flowing down over the outside of the pipe unit. The incoming cold cream is thus heated by the hot cream coming from the pasteurizer, and the outflowing hot cream is cooled by the cold, raw cream flowing to the pasteurizer.

Under average conditions the temperature of the cold cream is thus raised about 25-35° F. by the hot cream, and the temperature of the hot cream is lowered approximately 25-35° F. by the cold cream, thus accomplishing a considerable saving of heat and cold.

The Surface Cooler.—Under average plant operating conditions the surface cooler appears highly suitable for the cooling of flash-pasteurized cream. In order to avoid inconvenient height for operation and cleaning, the surface cooler is usually confined

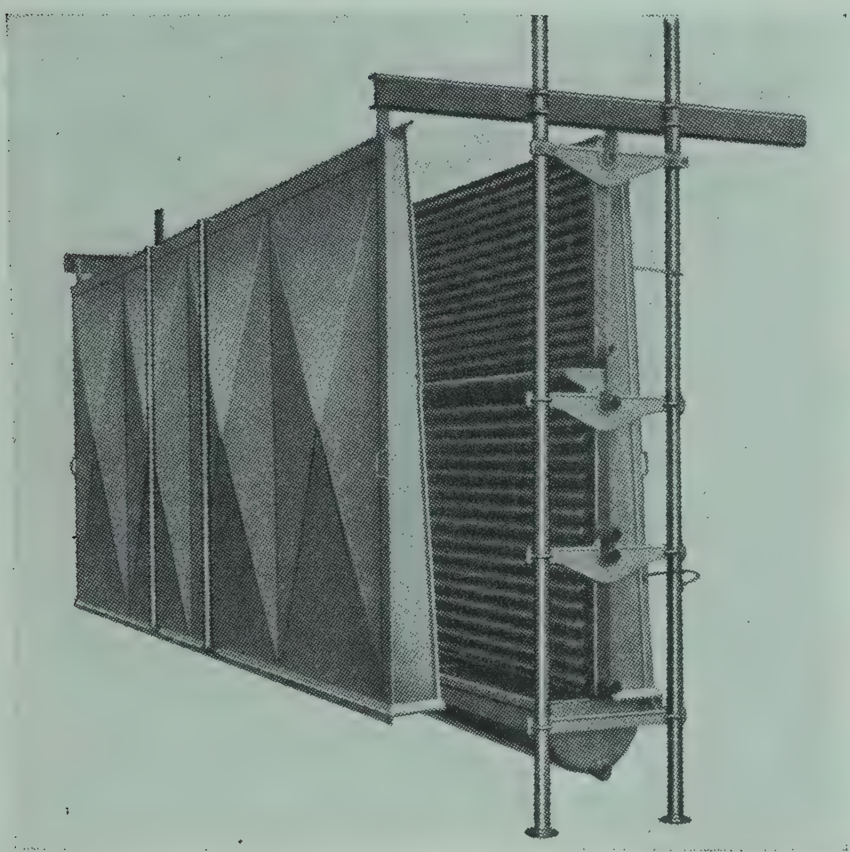


Fig. 45. Surface cream cooler with cover
Courtesy of Cherry-Burrell Corporation

to two sections, each arranged with independent intake and outflow for the refrigerant. The upper section is cooled with water and the lower section with brine or direct expansion ammonia.

The surface cooler has the added advantage of aerating the cream. This is especially desirable where steam jet pasteurization is practised for the purpose of volatilizing objectionable flavors, thus facilitating escape of the volatilized products from the cream that is flowing in a thin film over the outside of the surface cooler. The surface cooler also permits of some evaporation of moisture, which is desirable in the case of cream that has suffered dilution with steam condensate, as the result of steam injection pasteurization.

One of the drawbacks of the surface cooler is that it "breaks" the closed system of the cream flow. Unless the cooler

can be installed at an elevation high enough to permit the cooled cream to flow into the cream vat by gravity, an additional pump is necessary. In addition, the higher its elevation, the less accessible are its upper portions for proper cleaning. The cabinet surface cooler eliminates the objection of excessive height. This type of surface cooler consists of multiples of

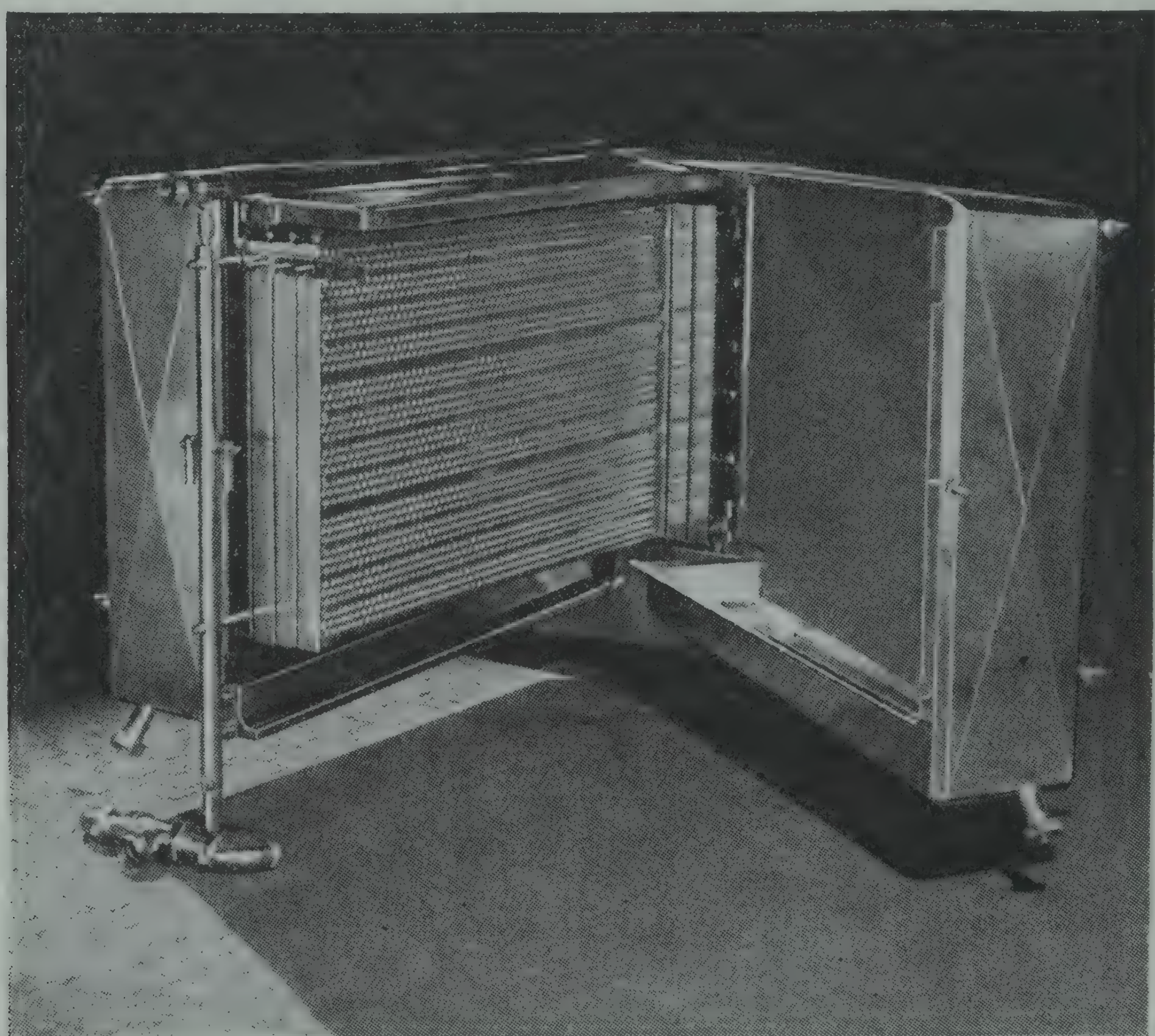


Fig. 46. Cabinet cream cooler
Courtesy of Cherry-Burrell Corporation

cooling tube sections, arranged on the same level, instead of one on top of the other as represented by the old-line surface cooler. The cabinet cooler has distinct advantages over the open surface cooler.

The Internal Tube Cooler.—The internal tube cooler consists of the two-tube principle, one inside of the other. The cream flows through the inner tube, while the refrigerant flows in counter-current between the inner and outer tube. The usual unit consists of one or two sections for water and one section for brine or direct expansion ammonia.

This type of cooler has the advantage of preserving the "unbroken," closed system of cream flow, discharging the cream

into the vats and up to any reasonable elevation without the need of a pump at the discharge end of the cooler. The internal tube cooler does not subject the cream to aeration. If aeration is desired it should be provided before the cream reaches this cooler.

In the case of sour, neutralized cream, the internal tube cooler usually does not permit of cooling to a temperature much below 60° F. without danger of the formation of a cream plug and of clogging. This tendency is especially prevalent when such cream has received severe prior treatment, such as, for instance, in connection with prolonged vacuumizing for removal of obnoxious flavors and odors. It is wisdom, therefore, to refrain from attempting to cool such cream to churning temperature (below 60° F.) in this cooler, and to finish the cooling to the final low temperature in the coil vat.

Forcing the cream through several standard sections of internal tube cooler, subjects it to considerable pressure, which further aggravates the tendency of cream in which the emulsion coefficient has already been lowered to near the "breaking" point, to churn either in the cooler or in the vat, causing delay and extra labor, and often costly loss of fat.

HOLDING OR BATCH PASTEURIZATION

Pasteurization of cream for buttermaking by the holding method, is done by the batch system, using the vat with coil agitator as the unit.

Vat Pasteurizers.—The vat pasteurizers in commercial use are of two general types, namely, jacketed vats with mechanical agitators, and vats without jacket, that are equipped with revolving or oscillating coil. In the jacketed vat the jacket supplies the heating and cooling element. The hot water, cold water, or brine, respectively, is sprayed against the jacket side of the heating surface. The cream is agitated by a series of blades moving to and fro lengthwise, or in the case of roun.. tanks, by a vertical, rotating wing agitator, or by one or more impellers.

Most of the coil vat pasteurizers are vats equipped with a revolving, helical coil. These pasteurizing vats are either oblong with horizontal coil, or square or round with vertical coil. In all vertical coil vats the coil is suspended from above, with

overhead drive, eliminating submerged stuffing boxes. The vertical coil has the further advantage, that its motion tends in the direction of releasing air from the cream, rather than beating air into the cream. Still another type of coil vat pasteurizer

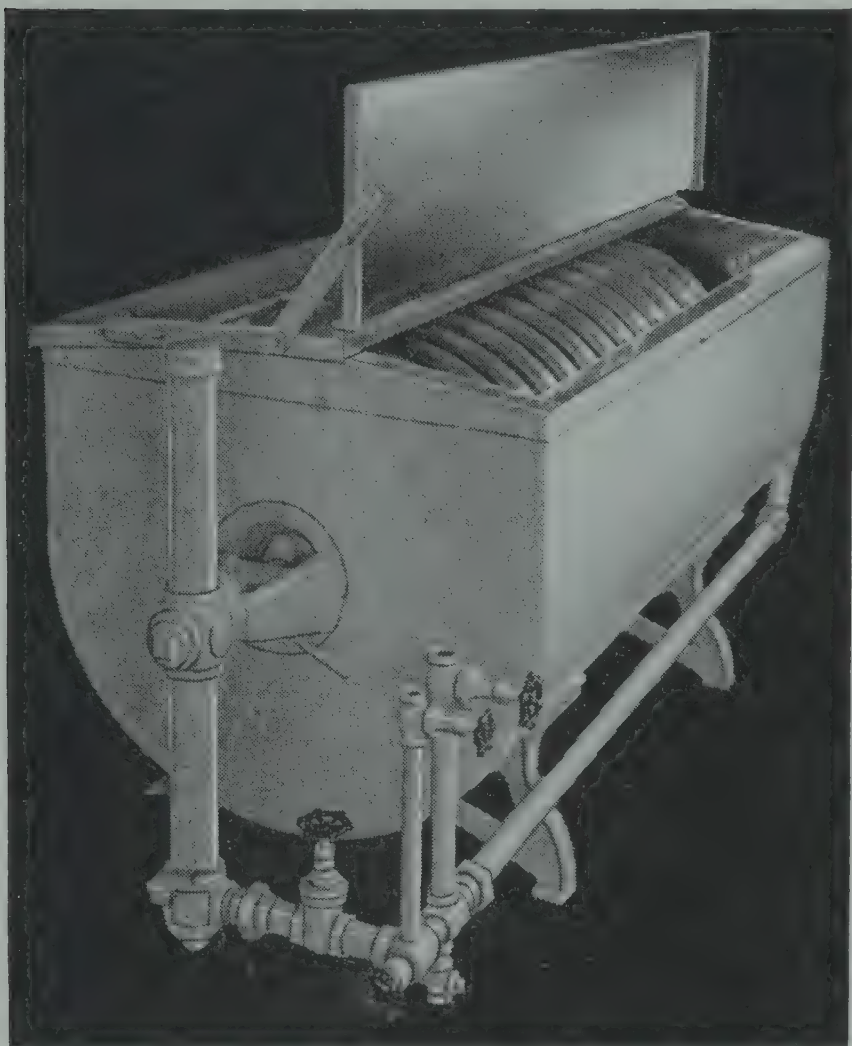


Fig. 47. Vat pasteurizer with horizontal coil
Courtesy of Creamery Package Mfg. Company

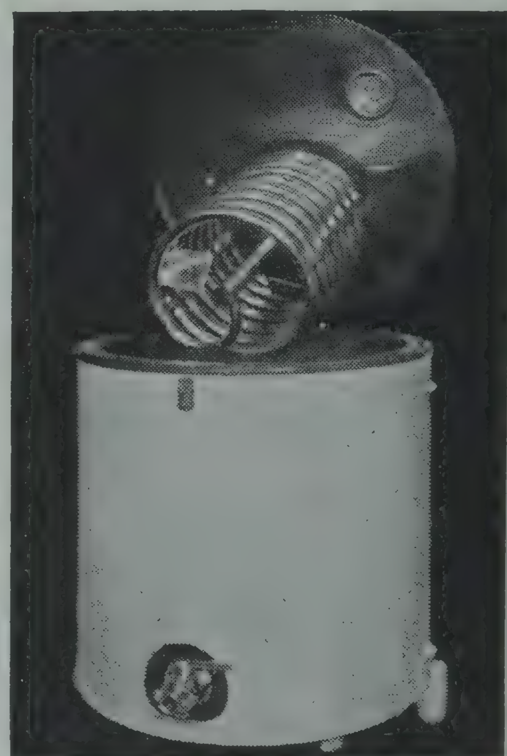


Fig. 48. Vertical coil vat pasteurizer
Courtesy of Pfaudler Co.

is that equipped with an oscillating or swinging section of straight pipes, in the place of the helical revolving coil. The pipe section here is suspended from bearings located above the surface of the cream. It swings from center to opposite sides of the vat and can be raised out of the cream when not needed, such as after heating, or cooling, or during the holding period.

A yet later type of vat pasteurizer is the Jensen Vacuum "A and G" machine. This is a jacketed vat with removable vertical coil similar in principle to that of the vertical coil vat, and with removable cover. This pasteurizer is connected with vacuum suction, thereby combining the air releasing feature of agitation by the vertical coil, with air-removal by vacuum suction.

The vat pasteurizer most commonly used in the creamery

is the oblong vat with helical horizontal coil. The coils usually have a tube diameter of 2 to 2½ inches. The heating surface varies somewhat with the size of the vat; small vats generally average a proportionately larger heating area than large vats.

Fig. 49. Elliptical coil vat pasteurizer

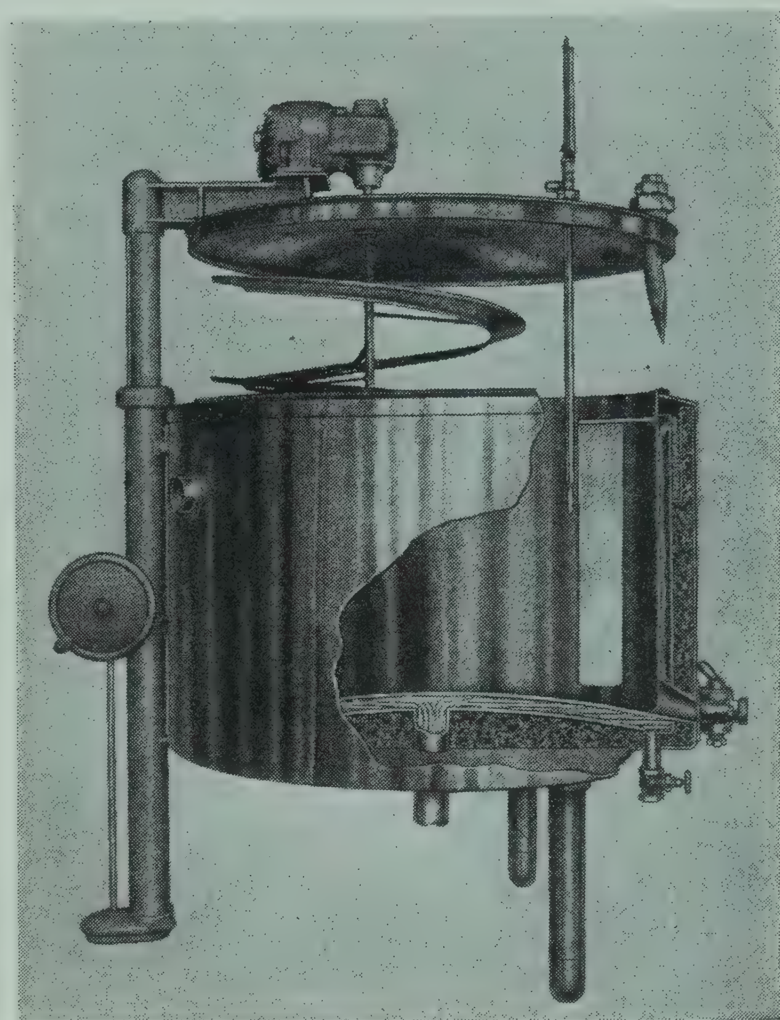


Fig. 50. Jensen Vacuum "A and G" vat pasteurizer

Courtesy of Jensen Machinery Co.

For efficient and reasonably rapid heating and cooling, the heating surface should not be less than about 20 square inches per gallon of cream.

Circulating Systems of Vat Pasteurizers.—The heating and cooling media are propelled through the revolving coil by either the self circulating system or the positive circulating system.

The self circulating system consists of admitting a small amount of air through the automatic air vent at the head of the coil shaft. As the air and water enter the coil, the air collects in the upper part of the coil, forming a cushion that separates the water column between successive coil convolutions. The revolving spiral coil causes the air cushion to push the water column forward, thus producing a partial vacuum behind the air plug, and this in turn draws in more water and air. The

coil discharges into the circulating tank at the rear of the vat, where the water is reheated by continuous steam injection and from where it returns to the head of the coil through a return pipe located underneath the vat. The operation thus repeats itself with each turn of the coil, making the circulation continuous. This system operates satisfactorily with hot water below about 170° F. At higher temperatures the water starts vaporizing in the revolving coil, because of the reduced pressure, the system becomes "steam bound," and circulation stops.

In the positive circulating system, the hot water is forced through the coil under pump pressure, and each convolution of the coil is completely full. The cooling medium is circulated in a similar manner as the hot water. It is customary to use water for cooling to about 90° F. and to finish the cooling to the desired temperature with brine or ice water. The water exhausts into the sewer and the brine is pumped back to the brine tank above, or flows to the brine tank by gravity, if located in the basement.

Vertical coils are not self-emptying. To prevent dilution or loss of brine when using both water and brine, the coil is emptied by means of compressed air. In the case of vertical coil vats equipped with jacket, the necessity of emptying the coil is eliminated by using the coil for heating, and for cooling with water only, and doing the brine cooling with the jacket.

Speed of Vat Coil.—The coil should be operated at the speed indicated by the manufacturer of the vat. The speed varies with size of coil, ranging about from 25 to 40 r.p.m. Insufficient speed retards heat exchange and renders uniform distribution of heat in all parts of the vat difficult. It also encourages the tendency of cooking the cream on the coil. Too high coil speed causes excessive foaming, splashing, and air incorporation in the cream.

Fullness of Vat Pasteurizer.—For best results the vat should be sufficiently full to completely submerge the coil. When part of the coil is exposed to the air, there is also a greater tendency for the coil to gather milkstone, and there is more splashing.

Temperature and Time of Heating and Cooling.—The heating and cooling should be done as rapidly as the steam supply and temperature of refrigerant, the available heating surface,

and the circulating system permit. Slow heating and slow cooling tend to give the resulting butter a mealy texture. See Mealy Texture, Chapter XXIII. Normally the heating of the cream to 145° F. does not occupy more than about 20 minutes. Persistent instances of excessive time required for heating and cooling suggest obstructions in coil or supply pipes.

The temperature-time exposure should conform with the standard and approved method of pasteurization by the holding process, i. e., 145° F. or above for 30 minutes. The general tendency on the part of the majority of creameries lies in the direction of using temperatures higher than 145° F. without shortening the holding period. Thus, many creameries are vat pasteurizing at 160° F. for 30 minutes and some even favor 170° F. for 30 minutes. Raising the temperature and retaining the full 30-minute holding period, obviously makes for somewhat higher germ-killing efficiency and destruction of enzymes. Above 160° F. the tendency is toward a more cooked flavor and slightly higher fat losses, and in the case of high-acid neutralized cream, the danger of oily-metallic flavor is augmented.

It is good practice to keep the vat covers up until the full pasteurizing temperature is reached. This assists in expulsion of objectionable volatile products, and it minimizes condensation on the vat covers. For the holding period the vat covers should be closed down to insure pasteurization of the foam on top of the cream. This also minimizes the tendency of a temperature drop. The coil should be kept revolving during the holding period to prevent oiling off.

In the absence of a sanitary flush valve a pail full of cream should be drawn from the vat gate at the beginning of the holding period and poured back into the vat, in order to insure full heat treatment of the cream in the gate nipple.

Because of the time exposure, vat pasteurization simplifies the problem of heating all the cream to the desired temperature. Yet there is need of vigilance on the part of the operator to make sure that the full pasteurizing temperature is actually maintained from beginning to end of the holding period. This is materially facilitated by equipping the vat pasteurizer with a properly functioning temperature recorder. In some states this accessory is required by law.

Combined Flash and Holding Pasteurization.—Under some conditions it is advantageous to flash heat the cream by running it through a flash pasteurizer into a vat for holding and cooling. This expedites the heating. In order to prevent a considerable drop in temperature during the holding period, the vat and vat gate should be steamed until "piping hot," immediately before the flash pasteurized cream enters, or the cream may be flash-pasteurized at a temperature about 5° F. higher than the temperature at which it is desired to hold it.

Steam Requirements for Pasteurization.—Ample boiler capacity that provides a uniform steam pressure, regardless of steam requirements for other factory operations, is essential for efficient pasteurization. In the absence of a plentiful supply of steam the routine of factory operations may have to be adjusted so as to avoid heavy drafts on the boiler for other operations at the time of pasteurization. For satisfactory temperature control the boiler steam pressure should not drop below 60 pounds.

EFFECT OF PASTEURIZATION ON PROPERTIES OF BUTTER

Effect on Wholesomeness of Butter and Buttermilk.—In the manufacture of food products, such as butter, the public health aspect demands foremost consideration. The creamery is without dependable means to determine the presence or absence of germs and viruses of disease in its milk and cream supply. Available experimental data indicate that, while the danger for butter to become a carrier of germs of disease is remote, the possibility nevertheless exists. It is imperative, therefore, that the standard of pasteurization of cream for buttermaking be such, as will dependably protect the consumer against the presence in butter of organisms and viruses of milk-borne diseases, such as tuberculosis, typhoid fever, undulent fever, diphtheria, scarlatina, septic sore throat, staphylococcus poisoning, etc.

North and Park,[6] as the result of a critical review of the literature on the thermal death periods for tubercle bacilli, and of their own extensive experiments, concluded that a standard of 142° F. for 30 minutes is the proper standard for pasteurization of milk. Their own results, in fact, show that the actual minutes required to kill B. tuberculosis at 142° F. was 10 minutes. They

further found that at 160° F. these bacilli were destroyed in less than 20 seconds. On the basis of the above accepted standard of 142° F. for 30 minutes, as the proper pasteurization standard, Dahlberg[7] calculated a series of temperature-time standards, comparable from the standpoint of margins of safety in protecting the public against disease organisms in milk. Dahlberg concluded that milk should be pasteurized at 145° F. for 13 minutes or at 160° F. for 16 seconds.

Pasteurization of Cream Provides Wide Margin of Safety.—The standards that have been established for the pasteurization of cream for buttermaking, which are 145° F. or higher for 30 minutes, and 180 to 185° F. or above for momentary exposure, and intermediate temperature-time combinations of equal or greater germ-killing efficiency, are capable of destroying microorganisms with thermal death points higher than those of the germs of the diseases above mentioned. The conclusion is inevitable, therefore, that pasteurization of cream for buttermaking, by the standard methods established, and when efficiently performed, provides even a wider margin of safety, from the public health viewpoint, than the accepted standard of pasteurization of milk.

Efficient pasteurization of cream for butter manufacture is a guarantee of freedom from agencies of disease. It safeguards the health of the consumer of butter and it protects the live stock interests against the danger of epidemics of infectious diseases caused by the feeding of buttermilk returned to the farm.

Effect of Pasteurization on Bacterial Counts.—Efficient pasteurization destroys the great majority of the yeasts and molds, and of the non-spore-forming bacteria present in the raw cream. Generally speaking, the higher the count of the raw cream, the larger the number of organisms that survive pasteurization, although the percentage destruction by pasteurization is usually greatest in the case of cream with a high original count.

Assuming that the original count in the raw cream is 300,000,000, and the count in the pasteurized cream is 300,000, the germ-killing efficiency is 99.9%. With a count of 30,000 in the same pasteurized cream it is 99.99%, and a count of 3,000 in the pasteurized cream gives a germ-killing efficiency of 99.999%.

These pasteurization efficiency figures check closely with

the experimental results of Hunziker and Cordes,[9] who found the pasteurizing efficiency of commercial flash pasteurization at 180 to 185° F. in the case of raw cream with from 132,000,000 to 580,000,000 bacteria to average 99.997%; and with the results of Hammer,[10] whose raw cream ranged from 167,000,000 to 825,000,000 bacteria and whose flash pasteurization at 180° to 185° F. yielded an average germ destruction of 99.999%. Hammer's results for vat pasteurization at 145° F. for 20 to 25 minutes averaged a germ-killing efficiency of 99.96%. Macy, Coulter and Combs[11] found holding pasteurization at 150° F. for 30 minutes more efficient than heating to 145° F. and bringing the temperature up to 165° F. during the 30 minutes holding period. They report that pasteurization destroyed 100% of the molds, from 88 to 100% of the yeasts and from 94.20 to 99.99% of the bacteria.

Wilster,[46] Fabricius,[47] and Brown[48] compared steam injection pasteurization by the Vacreator method with vat pasteurization. All three investigators reported a higher rate of germ destruction for vacreated cream than for vat pasteurized cream. The germ killing efficiency of vacreation appeared to be equal to and in some instances higher than that of standard flash pasteurization at 185° F. or higher. Roberts, Coulter and Combs[49] found steam injection pasteurization at 260° F. flash more efficient in germ destruction than vat pasteurization at 160° F. for 30 minutes; in practically every case the germ-killing efficiency by steam injection pasteurization at 260° F. was 100%. For details of vacreation and other steam injection-vacuum treatments of cream see Chapter XII.

Effect of Type of Organisms on Pasteurizing Efficiency.—Regarding the reaction of different types of micro-organisms to pasteurizing heat, the mass of experimental evidence shows unmistakably that the acid-producing bacteria (especially the lactics, the molds and most of the yeasts) are the least heat resistant. Exceptions reserved, they are readily destroyed at the lower pasteurizing temperatures. This is also true of many of the fat-splitting group of organisms. The proteolytic type, the organisms responsible for protein cleavage and decomposition, are somewhat more resistant to heat. Generally speaking, the higher pasteurizing temperatures appear somewhat more effective in eliminating the more resistant types of non-spore-

forming organisms. Guthrie, Scheib and Stark[12] observed that none of the non-spore-producing bacteria, found to be of importance in the spoilage of butter, were able to survive 165° F. for 30 minutes.

According to the work of Sherman, Stark, and Stark,[8] resistance to heat varies also with the physiological ages of the bacterial cells, a higher destruction of bacteria by pasteurization occurring in milk which has been held at temperatures which will allow the multiplication of the bacteria contained therein, than in milk of the same bacterial flora, but which has been stored at temperatures sufficiently low to inhibit bacterial growth. These investigators further show that "this difference in resistance to heat may be explained on the basis of the difference in age of the bacterial cells involved." These findings suggest the possibility of considerably greater resistance to heat and a tendency toward a lower percentage bacterial destruction in the case of old, stale gathered cream, than with fresh, sweet cream. It is further possible, though not experimentally proven, that the high fat content of cream exerts a protective influence that may enhance the heat resistance of the bacterial cells.

Effect of Pasteurization on Enzymes.—It has been definitely established that freshly drawn milk contains small amounts of several types of enzymes. In addition, milk and cream may contain enzymes produced by bacterial activity and metabolism, or that may result from disintegration upon the death of the cell. The more important enzymes relative to their effect on butter are those belonging to the lipolytic and proteolytic groups.

As shown under "Enzymes" in Chapter XXI, most of the enzymes are sensitive to pasteurizing temperatures. Pasteurization, either by the holding process or by the flash process, destroys some enzymes and diminishes the activities of others. The higher the pasteurizing temperature, or the longer the period of holding, the more pronounced is the inactivating effect. Guthrie et al.[12] concluded that pasteurization of cream at 165° F. for 30 minutes, destroys most, if not all of the harmful milk enzymes, but that all enzymes harmful to the keeping quality of butter were not destroyed at 145° F. for 30 minutes.

Effect of Pasteurization on Flavor of Butter.—Efficient pasteurization, intelligently adjusted to the character of the

cream, tends to benefit the flavor of the fresh butter. This improvement is attributable partly to the expulsion of slight objectionable volatile flavors that may be present in the cream, and partly to the destruction of germ life, making possible better control of fermentation between pasteurizer and churn.

In general, pasteurization of cream tends to give butter a more or less pronounced cooked flavor. When only slight, this character of flavor is not objectionable and it usually disappears before the butter reaches the market. The higher the temperature and the longer the exposure to high pasteurizing heat the more pronounced does the cooked flavor become. With normal quality of cream, suitable equipment, and proper operation, standard pasteurization at 145 to 160° F. for 30 minutes, or flash pasteurization at 180 to 185° F. produces butter in which the cooked flavor is either entirely absent or is negligible. See also Chapter XII on "Treatment for Removal of Objectionable Flavors."

Effect of Pasteurization of Sour Cream on Flavor of Butter.—The effect of pasteurizing temperatures on the flavor of butter varies materially with the character of the cream. Taking into consideration all types of cream, vat pasteurization at 145 to 160° F. for 30 minutes appears to offer the most dependable protection against objectionable pasteurization flavor defects.

Fresh, sweet cream will stand higher temperatures without developing an objectionable cooked or other off-flavor, than sour cream. High-acid cream, unneutralized, tends to produce butter with a disagreeable scorched, oily flavor, when pasteurized by the standard flash method at 180 to 185° F., while at 145 to 160° F. for 30 minutes, this objectionable flavor character is largely absent. This explains why the earlier pasteurizing experiments conducted with sour, unneutralized cream, invariably showed the fresh butter made from cream flash pasteurized at 180-185° F. to score lower than that made from vat pasteurized cream at 145 F. for 20 to 30 minutes, and occasionally even lower than the butter made from unpasteurized cream. This was the case with the work of Lee[13] (1909) who concluded that "pasteurization does not improve the quality of butter made from sour, farm-skimmed cream"; of Mortensen and co-workers[14] (1914) who, while reporting an improvement of flavor by pasteurization, concluded that vat pasteurization at 140 to

145° F. for 20 minutes yielded a higher scoring butter than flash pasteurization at 180 to 185° F.; of Hunziker and co-workers[15] (1917) who found that vat pasteurization at 145° F. for 20 minutes made higher scoring butter than either raw cream, or cream flash-pasteurized at 165° F. or at 185° F.

Effect of Pasteurization of Sour Neutralized Cream on Flavor of Butter.—The introduction of the practice of standardizing the acidity in cream before pasteurization, has greatly improved the results of high temperature pasteurization of cream with a high original acidity. In fact such cream may now be flash pasteurized at temperatures far above the boiling point of water, if desired, without serious damage to the flavor of the resulting butter, provided that heat exposure and especially heating up to and cooling down from these high temperatures, are done quickly and that the cream is churned within one to two hours after cooling.

Relation of Pasteurization to Oily-Metallic Flavor.—Experience has further demonstrated that the temperature range of 170 to 190° F., and particularly 175 to 185° F., constitute a critical temperature area for a certain type of high-acid, neutralized cream, causing such cream, if held for more than 1 to 2 hours before churning, to yield butter with an objectionable oily-metallic flavor. The danger of this damage to flavor appears to be greatest with high-acid cream that is abnormally rich in fat. At pasteurizing temperatures below 165° F. the oily-metallic flavor appears to be completely absent. At temperatures above 212° F. (especially within the range of 230 to 260° F.) there is less tendency toward oily-metallic flavor than between 170 and 212° F. The oily-metallic flavor does not appear at any temperature of pasteurization in the case of sweet cream or cream that was only slightly sour before neutralization.

Pasteurization Does Not Eliminate Fermentation Flavors from Poor Quality Cream.—Efforts to improve the quality of Grade II cream, such as stale, cheesy, rancid, metallic, yeasty cream, by the use of abnormally high pasteurizing temperatures, usually yield disappointing results. These old-cream defects are not volatilizable at any practicable temperature of pasteurization. On the contrary the intense heat appears to magnify them and to make them more pronounced. There is no known temper-

ature-time combination of pasteurization that will make No. 1 butter from Grade II cream.

The fresher and sweeter the cream, the fewer and simpler are the problems of pasteurization, and the easier it is to secure the desired results without jeopardizing the flavor. As the character of the cream deviates increasingly from that of normal sweet cream, more attention must be paid to the handling of the cream preparatory to pasteurization, and to the proper adjustment of the process of pasteurization relative to the sensitiveness of the cream to heat.

EFFECT OF PASTEURIZATION ON KEEPING QUALITY

Butter made from properly pasteurized cream keeps better than butter made from raw cream. This is true of both salted and unsalted butter, whether made from fresh sweet cream, sour cream, or sour neutralized cream, and whether held in cold storage or at ordinary temperatures.

Proper appreciation of the possibilities and limitations of the effect of pasteurization of cream on the keeping quality of butter compels recognition of the fact that keeping quality is controlled by two separate and distinct forces, namely; bacterial activity and chemical reactions. Lack of keeping quality, such as results in the deterioration of flavor and the development of off-flavors, may be caused by the action of bacteria and enzymes, or it may be due to purely chemical reactions. These two groups of causes may be interrelated and dependent, one upon the other; or they may be entirely independent of each other; or they may even be antagonistic to each other in the sense that efforts to eliminate the one group of causes, may incite, or intensify the action, and magnify the damage done, by the other group of causes.

Pasteurization Does Not Prevent Storage Flavor.—For butter held in commercial cold storage (at the usual temperatures of 10 to 20° F. below zero), keeping quality is not a biological problem. As shown by the work of Macy,[16] Jacobsen,[17] Grimes,[18] Washburn and Dahlberg,[19] Macy, Coulter & Combs,[11] and others, the bacterial count of both salted and unsalted butter decreases. At these low temperatures the microorganisms not only fail to grow, but they actually suffer a gradual dying off. Keeping quality of butter held in commercial cold storage

is not materially affected by the pasteurization of cream; it is, in fact, essentially a problem of quality of cream. With the churning acidity adjusted below the danger point from the standpoint of fishy flavor, butter made from fresh, sweet pasteurized cream shows very little age deterioration in cold storage, while the butter made from sour, fermented, neutralized, pasteurized cream, invariably develops the characteristic cold storage flavor defect. Such butter usually is high in soluble nitrogen compounds and its flavor deterioration is in all probability due to progressive oxidation of some of the non-fatty constitutents (especially the protein), as pointed out by Dyer.[20]

Pasteurization Beneficial to Butter of Every Phase of Disposition.—However, whether intended for cold storage or not, butter is exposed for varying and frequently protracted periods of time to temperatures favorable to germ growth. In the case of cold storage butter there is the period from churn to cold storage and from cold storage, often by very indirect routes, to the table of the consumer. A large portion of the annual output of butter does not enter commercial cold storage, and yet its journey from churn to ordinary cooler, to wholesaler, to jobber, to retailer, and to consumer may extend over many weeks and even several months. This butter is exposed to a wide range of temperatures, most of which are well within conditions favorable to bacterial development and enzyme activity. It is inevitable, therefore, that bacterial deterioration of butter is an ever-present menace, and that the keeping quality-protecting influence of efficient pasteurization enters into every phase of butter disposition.

Relation of Bacterial Count to Keeping Quality.—Attempts at a correlation of pasteurizing efficiency, as expressed by total counts of bacteria, with the keeping quality of the resulting butter not infrequently yield results that appear inconsistent and confusing. While such comparisons show wide variations, yet the general trend lies in the direction of the lower counts for the better keeping quality. This trend is shown by the work of Lund,[12, 22, 23] Bouska and Brown,[24] North and Reddish,[25] Redfield,[26] Stiritz,[27] Shutt,[28] Hood and White,[29, 30, 31] Parfitt,[32] Gregory,[33] Macy,[34] Johns,[35] Macy and Richie,[36] and Demeter and Maier.[37] The results all point in the same direction, justifying the conclusion voiced by Macy and Richie,[36] that, in the case of

individual samples, the mold, yeast, and total bacterial count fails to provide a reliable index to the keeping quality of the butter, but that as a group, the samples of butter with the lower mold, yeast, and total bacterial count show a tendency toward a slightly better keeping quality. These experimental findings are in harmony with commercial experience, to the effect that efficient pasteurization that accomplishes a low bacterial count, improves the general keeping quality of butter.

Hammer and Hussong[38] also observed that "many species of organisms can develop in butter until enormous numbers are present, without seriously affecting flavor and aroma, but that certain types are very definitely objectionable, and comparatively small numbers can bring about a conspicuous deterioration." Nelson[39] likewise concluded that keeping quality was not so directly related to numbers as to types of organisms present, as determined morphologically, and that no sample would show good keeping quality when small, thin rods predominated, while a predominating flora of micrococci had apparently no influence on keeping quality.

Pasteurization Prevents Specific Bacterial Defects.—Another very important aspect of the influence of pasteurization on keeping quality is, that pasteurization constitutes an effective and dependable means of preventing the development in butter of specific bacterial flavor defects resulting from profuse contamination of the raw cream with the causative germs, as for example such economically disastrous defects as rancidity and surface taint (putrid flavor).

These and similar definite bacterial defects are the result of definite contamination with specific organisms. In order for these defects to develop in butter, the causative organisms must be present in sufficient number to enable them to gain the ascendency in the mixed bacterial flora of the butter. Although bacterial analyses of such butter often fail to show large numbers of the organisms directly responsible for the specific defect, such butter usually, though not always, yields an abnormally high total count.

The destruction of bacterial cells and enzymes contained in the cream, that results from efficient pasteurization, is adequate to protect the butter against these specific bacterial flavor defects, provided that the sanitary status of equipment, manufac-

ture and handling between pasteurizer and consumer's package is such as to preclude damaging recontamination after pasteurization. This is the case with both salted and unsalted butter.

Pasteurization of Cream Intended for Unsalted Butter.—Pasteurization is obviously a controlling factor in the keeping quality of unsalted butter, both from the standpoint of preventing specific bacterial defects, and of retarding general age deterioration. Bacteriological study of unsalted butter has conclusively shown that, when held at temperatures above the freezing point, there is uninterrupted increase in the bacterial count. Efficient pasteurization of the cream, preferably followed by proper ripening with a good starter, not only retards the general age deterioration that is characteristic of all unsalted butters, but it prevents the early appearance of the more serious flavor defects that result from the presence in cream of specific, flavor-damaging organisms.

Pasteurization of Cream Intended for Salted Butter.—In salted butter the increase or decrease of organisms in butter held at temperatures above the freezing point depends largely on the salt concentration. In the case of a salt content of 2 to 2.5 per cent the tendency is toward a decrease. When made from efficiently pasteurized cream, and under conditions that preclude copious recontamination after pasteurization, damaging flavor deterioration in such butter due to bacterial causes is remote. However, even in the presence of a salt content of 2.5%, salted butter is by no means immune to the ravages of damaging bacterial contamination. It will readily develop rancidity or surface taint (putrid flavor), or other flavor defects, in the presence of specific contamination. Absence of pasteurization, or inefficient pasteurization constitute prolific causes of these defects, while efficient pasteurization is a dependable protection of salted butter against their development.

Relation of Temperature of Pasteurization to Keeping Quality of Butter.—It was shown that high temperature flash pasteurization is more destructive to germ life than the lower temperatures of the holding process. It was also pointed out that there is a tendency for butter with a low bacterial count to have better keeping quality than butter with a high bacterial count. These facts emphasize the wisdom of the assertion of

the able Danish butter experts, Knudsen & Jensen,[40] who sum up their conception of the bacteriological status of good-keeping butter as follows: "Les organismes qui ne doivent pas être dans le beurre, doivent être écartés" (The organisms which should not be in the butter, should be eliminated from it). In general it follows, therefore, that high temperature pasteurization makes for maximum keeping quality.

In further support of this conclusion may be cited the work of Ritter,[41] who reports that flash pasteurization at 194° F. prevents fishy flavor, and by Mohr and Ritterhoff,[42] whose experiments with "Dauerbutter" (storage butter) convinced them that holding pasteurization at 143 to 149° F. for 30 minutes was inadequate and who recommend flash pasteurization at 197 to 203° F. for best results. These conclusions are also supported by the long-established practice of the great butter-exporting countries, Denmark, New Zealand and Australia. These countries are successfully competing for supremacy on the World butter market. They have been consistently flash-pasteurizing their cream at high temperatures (190 to 200° F.). To these countries the manufacture of butter that will bring top price is an economic necessity. Their long experience has convinced them of the importance of efficient pasteurization as a means to satisfy a critical trade. They have learned to regard efficient pasteurization and high temperature pasteurization as synonymous.

Merits of Pasteurization by the Holding Process.—These facts in favor of high-temperature pasteurization for butter of maximum keeping quality should not be interpreted in the sense of disqualifying vat pasteurization at 145-160° F. for 30 minutes. This process has its proper place in our industry, and it has distinct advantages over high-temperature flash pasteurization under some of the conditions prevailing on this continent.

Its simplicity and economy of equipment and operation render it especially well adapted for use in the creamery with moderate volume. It is suitable for every character of cream. It yields butter that is freer from objectionable cooked flavor than any other time-temperature combination of pasteurization. It does not cause an oily-metallic flavor in the case of high-acid cream, that is rich in fat. Its germ-killing efficiency is sufficient to render the butter safe for consumption. It can be depended

upon to prevent the development of specific bacterial flavor defects, such as surface taint (putrid flavor) and rancid flavor. Years of experience with this process have demonstrated its adequacy to yield butter with satisfactory keeping quality for fresh consumption, for short-held purposes and for long-held commercial cold storage.

Effect of Pasteurization on Texture and Body of Butter.—Pasteurization of cream, when properly performed, does not injure the body and texture of butter. The chief danger in the case of faulty pasteurization lies in the tendency to produce butter with a mealy texture. This may result from excessively long exposure to heat and from too slow cooling.

In the flash process, which provides instantaneous heating and cooling, this danger is almost completely eliminated, and is present only when underfeeding the pasteurizer in a manner that causes the cream to stay in the hot machine too long. In the case of the steam jet method of pasteurization, particularly when operated under reduced pressure, such as applies to the Vacreator process, the tendency is, in fact, in the direction of an improved body and texture. See also Chapter XII.

In the holding process mealiness may occur, when too much time is consumed in bringing the temperature up to the desired point and when the cooling is greatly retarded. Vat pasteurization, properly done, yields butter with good body and smooth texture.

Effect of Pasteurization on Chemical Composition of Butter.—Pasteurization has no appreciable effect on the composition of butter. Such slight differences as may occur are overshadowed by the effect of the treatment which the butter receives in the working process, and which standardizes the two chief constituents; namely, the fat and the moisture.

There is a tendency for the curd content of pasteurized cream butter to be slightly lower than that of raw cream butter. Pasteurization also tends to reduce the acidity in butter slightly. This is due to the expulsion from cream of carbon dioxide gas and other volatile acids.

EFFECT OF PASTEURIZATION ON FAT LOSSES IN THE BUTTERMILK

The pasteurization of sour cream increases the fat test of the buttermilk. This appears to be principally due to the rela-

tively low heat coagulation point of sour cream. At the usual pasteurizing temperature the sour cream curdles. Each curd particle "locks up" some fat. Since the bulk of the curd passes into the buttermilk, the fat so "locked up" increases the fat lost. That the fat of buttermilk from churnings of cream pasteurized while sour is, in fact, largely concentrated in the curd portion, was demonstrated by Hunziker and Mills,[43] who allowed un-neutralized, sour-cream buttermilk to settle, and analyzed the curd portion and the clear whey separately. The whey showed traces of fat only, while the curdy layer, representing approximately one-fifth of the total volume of the buttermilk, contained from about 1.5 to 4% of fat.

Effect of Temperature.—In general, the higher temperatures of flash pasteurization tend in the direction of higher fat losses than the lower temperatures of vat pasteurization. This appears to be particularly the case with sour, and with sour neutralized cream. The study of fat losses in commercial butter manufacture over a period of years by Hunziker,[44] showed the buttermilk tests in vat pasteurizing plants (145 to 150° F. for 30 minutes) to range from 0.30 to 0.65%, averaging approximately 0.45% fat, while in flash pasteurizing plants (standard flash pasteurizer with steam jacket and revolving wing agitator, temperature 180 to 185° F.), the buttermilk tests ranged from 0.50 to 1.15%, averaging approximately 0.65 to 0.70%. It is probable that the higher flash pasteurizing temperatures augment the heat-curdling effect in the case of the sour neutralized cream, causing more fat to pass into the buttermilk with the curd. In addition, it is conceivable that the more intense agitation of flash pasteurization brings about such reduction in the size of the fat globules, as to increase the proportion of very minute globules that escape into the buttermilk.

Effect of Method of Pasteurization.—The effect of temperature on fat losses discussed in the foregoing paragraphs refers to the standard flash pasteurizer in which the cream is heated by contact with a heated metal surface. In the case of the steam jet pasteurizer in which the cream is heated by injection of "live steam," the buttermilk test, when pasteurizing at 180 to 185° F., is similar to that from standard pasteurization at the same temperature, with a tendency upward rather than downward. Unless accompanied, or followed by vacuum treatment, however, the

total fat loss is considerably greater due to dilution that increases the volume of buttermilk. This dilution averages approximately 10% of the original volume of cream. In the presence of vacuum treatment, this dilution is partly or wholly offset by evaporation.

Higher temperatures, such as above the boiling point, tend to further increase the per cent fat lost in the buttermilk. Factory experiments by Hunziker and Harris,[45] in which the pasteurizing temperature was raised to 250° F., showed as high as 1.3% fat in the buttermilk. Similar results were reported by Roberts, Coulter and Combs.[49]

Here again, the tendency toward more intense curdling action at the higher pasteurizing temperature, and the increased effect of splitting up the fat globules due to the more severe impingment of steam and cream under pressure, may be largely responsible for the lesser exhaustiveness of churning, and the increase in the buttermilk test. The effect on fat losses may involve also a change in the nitrogenous protective film that surrounds the fat globules.

REFERENCES

1. HUNZIKER, O. F., and CORDES, W. A., Blue Valley Res. Labs. (not publ.), (1938).
2. McDOWELL, F. H., N. Z. Jour. Sc. and Tech. X, *5*, 275, (1929).
3. GELPI, A. J., JR., and DEVEREUX, F. D., J. D. Sc. XIII, *5*, 368, (1930).
4. TRACY, P. H., J. Bact. *24*, 423, (1932).
5. ROBERTSON, A. H., YALE, M. W., and BREED, R. S., N. Y. (Geneva) Agr. Expt. Sta. Tech. Bul. 119, (1926).
6. NORTH, C. E., and PARK, H., Am. J. Hyg. VII, 147, (1927).
7. DAHLBERG, A. C., N. Y. (Geneva) Agr. Expt. Sta. Tech. Bul. 203, (1932).
8. SHERMAN, J. M., STARK, C. N., and STARK, P., J. D. Sc. XII, *5*, 385, (1929).
9. HUNZIKER, O. F., and CORDES, W. A., Blue Valley Res. Labs. (not publ.), (1926).
10. HAMMER, B. W., Ia. Agr. Expt. Sta. Bul. 156, (1914).
11. MACY, H., COULTER, T. S., and COMBS, W. B., Minn. Agr. Expt. Sta. Tech. Bul. 82, (1932).
12. GUTHRIE, E. S., SCHEIB, B. J., and STARK, C. N., J. D. Sc. XIX, *4*, 267, (1936).
13. LEE, C. E., Ill. Agr. Expt. Sta. Bul. 138, (1909).
14. MORTENSEN, M., GAESSLER, W. G., and COOPER, W. H., Ia. Agr. Expt. Sta. Bul. 156, (1914).
15. HUNZIKER, O. F., SPITZER, GEO., MILLS, H. C., and SWITZER, H. B., Purdue Agr. Expt. Sta. Bul. 208, (1917).
16. MACY, H., J. D. Sc. XIII, *3*, 266, (1930).
17. JACOBSEN, D. H., J. D. Sc. XXI, *4*, 187, (1938).
18. GRIMES, M. A., J. D. Sc. VI, *5*, 427, (1923).
19. WASHBURN, R. M., and DAHLBERG, A. C., J. D. Sc. I, *2*, 114, (1917).
20. DYER, D. C., J. Agr. Res. VI, 24, (1916).
21. LUND, T. H., Abstr. Bact. V, (1921).

22. LUND, T. H., N. Y. Prod. Rev. and Am. Cry. 516, (1921).
23. LUND, T. H., Cry. & Milk Plant Monthly X, 1, (1921).
24. BOUSKA, F. W., and BROWN, J. C., Wis. Univ. Stud. Sci. No. 2, 131, (1921).
25. NORTH, W. R., and REDDISH, G. F., J. D. Sc. IV, 510, (1921).
26. REDFIELD, H. W., J. D. Sc. V, 14, (1922).
27. STIRITZ, B. A., J. D. Sc. V, 362, (1922).
28. SHUTT, D. B., J. D. Sc. VII, 357, (1924).
29. HOOD, E. G., and WHITE, A. H., Dom. Can. Dept. Agr. Bul. 48, (1923).
30. HOOD, E. G., and WHITE, A. H., Dom. Can. Dept. Agr. Bul. 48, N. S., (1925).
31. HOOD, E. G., and WHITE, A. H., Dom. Can. Dept. Agr. Pamph. 92, N. S., (1928).
32. PARFITT, E. H., Cry. and Milk Plant Monthly XL, 53, (1926).
33. GREGORY, H. W., Butter, Cheese and Egg Jour. Feb., (1927).
34. MACY, H., J. D. Sc. X, *384*, (1927).
35. JOHNS, C. K., Sc. Agr. VIII, 353, (1928).
36. MACY, H., and RICHIE, H. B., J. D. Sc. XII, *4*, 351, (1929).
37. DEMETER, K. J., and MAIER, F. X., Milchw. Forsch. XI, *4* and *5*, 437, (1931).
38. HAMMER, B. W., and HUSSONG, R. V., Ia. Agr. Expt. Sta. Res. Bul. 134, (1930).
39. NELSON, J. A., Mont. Agr. Exp. Sta. Bul. 267, (1932).
40. KNUDSEN, S., and JENSEN, M., Le Lait XIII, 127, (1933).
41. RITTER, W., XI Milchw. Cong. Berlin. II, 162, 1937).
42. MOHR, W., and RITTERHOFF, MOLK, Zeitg. Hildesheim 28-29, (1938).
43. HUNZIKER, O. F., and MILLS, H. C., Purdue Agr. Expt. Sta. (not publ.), (1915).
44. HUNZIKER, O. F., Blue Valley Cry. Co., Factory Expts. (not publ.), (1930-39).
45. HUNZIKER, O. F., and HARRIS, R. C., Blue Valley Cry. Co. Factory Expts. (not publ.) (1938).
46. WILSTER, G. H., Ore. Agr. Expt. Sta. Bul. 368, (1940).
47. FABRICIUS, N. E., Ia. State Coll., by Correspondence, (1940).
48. BROWN, R. W., Univ. Manitoba, by Correspondence, (1940).
49. ROBERTS, W. M., COULTER, S. T., and COMBS, W. B., J. D. Sc. XXIII, 1940.

CHAPTER XII

TREATMENT OF CREAM FOR THE REMOVAL OF OBJECTIONABLE FLAVORS AND ODORS

In general, objectionable flavors that are present in the cream at the churn, reappear in the resulting butter, damaging its market value. The various types of off-flavors that may appear in cream, and their origin or cause are discussed in detail in Chapter XXIII under "Flavor Defects."

Methods of Removing Objectionable Flavors and Odors.—The attempts made and the methods devised by the industry, to remove objectionable flavors and odors from cream are numerous and of diverse nature. These methods are grouped below in accordance with the major principals involved and are described briefly in succeeding paragraphs:

1. Volatilization of the off-flavor by heat and expulsion of the volatile products.
2. Removal of non-fat constituents by re-separation of the cream.
3. Removal of non-fat constituents by successive re-separation and washing of the cream.
4. Treatment of cream with chemicals.
5. Treatment of cream with carbon dioxide gas.

1. Volatilizing the Objectionable Flavors by Heat and Expelling the Volatilized Products.—It has long been recognized that, if the objectionable flavors of cream could be made volatile, they could be more readily expelled. The underlying thought of this theory is not new, but years of experimenting with methods of heating, degree of heat and manner of expulsion, were necessary to arrive at the present state of understanding of the possibilities and limitations of cream treatment of this nature. Assuming that every off-flavor has its own volatilizing temperature, it would follow that, if the cream is heated to a temperature sufficiently high, practically all the off-flavors that it may contain would be volatilized. Once volatilized, the next

step must be to expel the volatile products quickly and completely enough to prevent their re-absorption by the cream. It has been realized also that for both, maximum volatilization and completeness of expulsion of the volatilized products, the cream must be reduced to the smallest possible particle size, so as to expose the largest possible surface for the escape of the products that have been made volatile.

In 1914 Ayres and Johnson[1] published experiments on removing onion flavor from sweet milk and sweet cream by forced aeration. In 1920 Hunziker[2] designed an apparatus and developed a method, on which U. S. patent was granted in 1925, for removing onion flavor from sour, neutralized cream on a commercial scale, by blowing air through a continuous shower of flash-pasteurized cream. In 1922, in conjunction with the Pfaudler Company of Rochester, N. Y., he designed equipment for accomplishing this treatment with heated air in a vacuum pan, later known as the Pfaudlerizer, on which U. S. patent was granted in 1929. The explosion of the hot cream upon entering the vacuum pan and the rapid removal of the volatile products by the vacuum suction expedited the expulsion of the off-flavors that had been made volatile by heat. The later use of steam injection in the place of heated air, materially improved the efficiency of the Pfaudlerizer.

Volatilizing with Live Steam and Expulsion of Volatilized Odors in Vacuo.—The flavor-removing efficiency of the treatment of cream was materially augmented by the advent of heating the cream under pressure, preferably to temperatures above the standard temperature (185° F.) of flash pasteurization, by injecting into and dispersing through the cream, high-speed jets of dry steam, followed by atomization in a partial vacuum. As early as 1920 Grindrod[3] evolved the principle of "Impact Sterilization," U. S. patent application filed in 1924, and patents granted in 1929 and subsequently. This process consisted of injecting high-pressure, dry steam through needle jets into the milk or other fluid held in a closed container, and releasing the milk into a high vacuum. The original purpose was to accomplish sterilization at temperatures below the usual sterilizing temperature (245° F.) for evaporated milk. The theory of sterilization by this process was, that the injection of high-speed needle steam jets into the fluid destroys germ life

by tearing the living cells apart. The purpose was to sterilize. No claim was made for removal of objectionable flavors, although the process did eliminate such flavors incidentally.

Application of the principle of heating by steam injection, accompanied or followed by vacuum treatment, has given birth to numerous designs of patented equipment and processes, assembled for the specific purpose of removing objectionable flavors and odors from cream. To the better known machines that are in commercial use in creameries today, belong the American (U. S. A.) units — the Jensen Super-Deodorizer, the Rogers High-Temperature Pasteurizer, and the Sealtest Process for Treating Lactic Fluids. Among the well-known units of other countries are the Vacreator Vacuum Pasteurizer of New Zealand, and the Volatiliser of Australia. The general construction and operation of these machines is briefly outlined in succeeding paragraphs.

The Jensen Super-Deodorizer.—This machine is manufactured by the Jensen Machinery Company of Bloomfield, N. J. Its present type is based on earlier designs utilizing a vacuum chamber into which a mixture of cream and "live" steam was introduced. The Super-Deodorizer is of simple and compact design. It consists of a tall, cylindrical type vacuum chamber, the lower half being hot water-jacketed.

The upper part of the chamber is provided with a cream receiving pan (cream expansion pan) in which the cream is subjected to the first action of the vacuum. The cream outlet from the expansion pan leads to a steam supply line, equipped with steam injector device. Release of the cream and steam mixture into the main vacuum chamber is made upon a distributing cone. The machine is equipped with a jet-type condenser, vapor-removing pipe, entrainment trap, cream inlet tank, cream removal pump and necessary controls for maintenance of uniform vacuum and temperature.

The hot, pasteurized cream enters the cream expansion pan located above the main vacuum chamber, where it receives preliminary or first stage vacuum treatment, "expanding" it. From here it is drawn through the steam injection device which provides intimate intermingling of steam and cream. The flow of cream to the steam nozzle is regulated by the suction of the vacuum in combination with a float valve in the cream receiving tank located on the outside of the deodorizer. The mixture of

cream and steam then enters the main vacuum chamber. Here it is released upon a distributing cone from which it impinges upon the walls of the deodorizer and travels vertically along

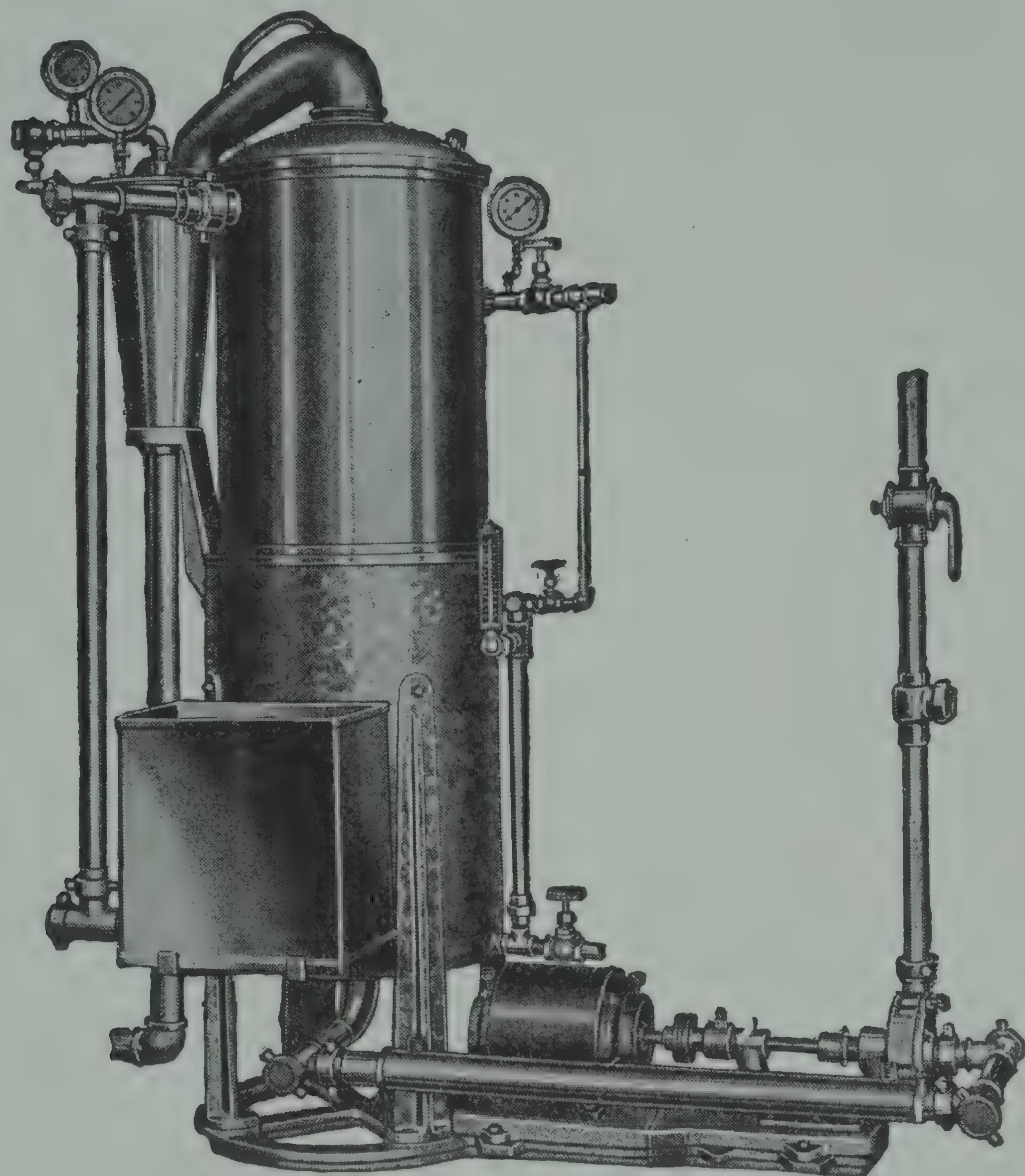


Fig. 51. Jensen super-deodorizer
Courtesy of Jensen Machinery Co.

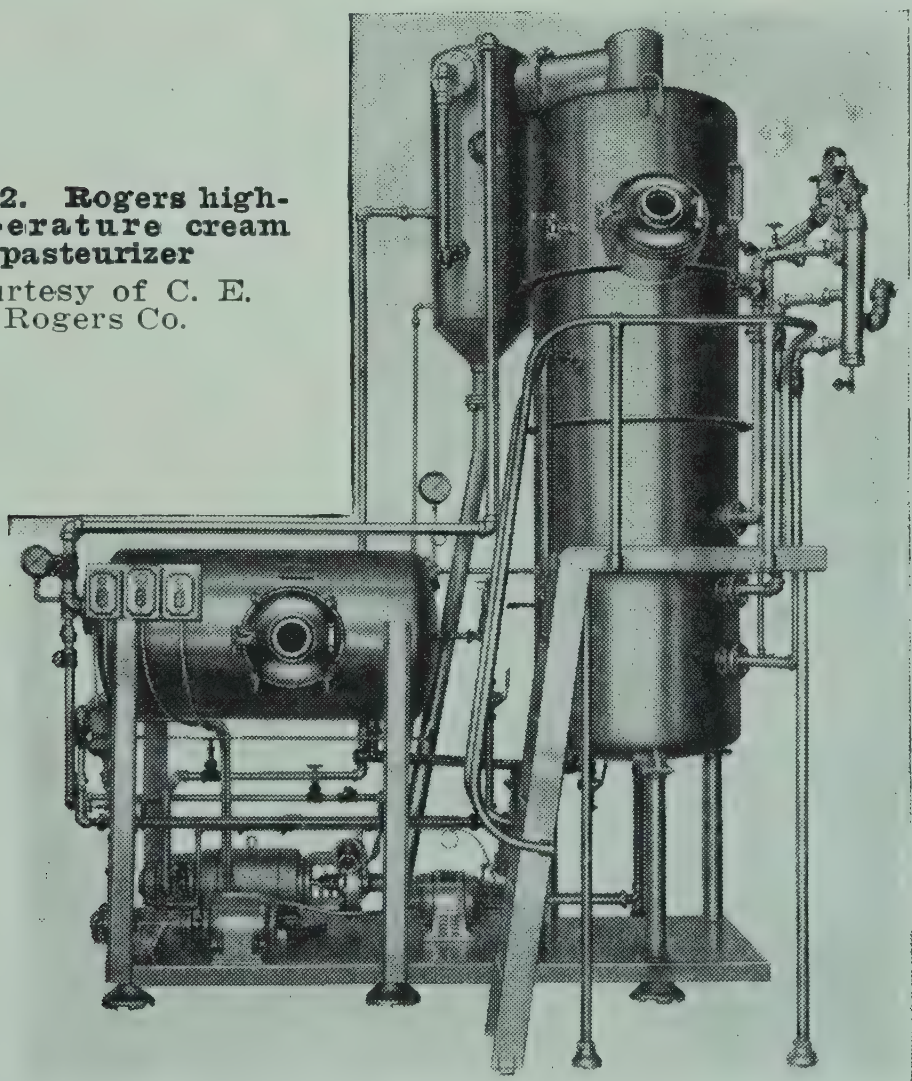
the walls to the bottom. The hot water jacket provides means for heating and controlling the temperature of the cream. The liberated gases and vapors escape through the vapor pipe to the condenser. The vacuum and steam volume used varies with the character of the cream. The temperatures of the cream supply recommended by the manufacturer, range from vat pasteurizing temperature (145 to 160° F.) to flash pasteurizing temperature (180° F. or higher).

The Rogers High Temperature Cream Pasteurizer.—The initial equipment and process, U. S. patent applied for in 1923. and patent granted in 1926, refers to heating the cream to 180-185° F. Later patents, applied for in 1934 and 1935 and patents granted in 1938, cover heating to above 212° F., and as high as 300° F.

The equipment, in its present form (1940), consists of a high temperature, steam jet pasteurizer with two-stage vacuum deodorizers and coolers. The preheated neutralized cream is pumped under pressure into and through a pasteurizing tube where dry steam is injected into the cream, heating it instantly to the desired temperature. The temperature is regulated according to the condition of the cream and the type and intensity of off-flavors it contains. The temperatures may range from below 212° F. to 300° F.

From the pasteurizing tube the heated cream discharges into the first vacuum chamber which is equipped with a special cream diffusion head. The drop from high pressure to partial vacuum causes the cream to atomize into a fine mist, facilitating the removal of objectionable flavors volatilized at the high tem-

Fig. 52. Rogers high-temperature cream pasteurizer
Courtesy of C. E. Rogers Co.



perature in the pasteurizing tube. Simultaneously, the temperature of the cream drops to a point (approximately 180 to 190° F.) corresponding to the lower boiling point in the partial vacuum of about 11-15 inches.

The higher vacuum (about 26 inches) maintained in the second chamber (which is a standard vacuum pan) draws the

cream from the first to the second vacuum chamber through a dispersion jet that atomizes it a second time and at this stage under a higher vacuum, which lowers its temperature to approximately 130° F. The odor-laden vapors from both vacuum chambers escape through the condenser where they are condensed and voided through the vacuum pump. The deodorized cream is drawn from the bottom of the second vacuum chamber by a centrifugal cream pump and cooled in the usual manner.

The Sealtest Process for Treating Lactic Fluids.—Practically simultaneously with the Rogers process, but independently, the Sealtest process was developed by B. W. Hammer, H. C. Horneman and M. E. Parker, assignors to Sealtest System Laboratories, U. S. patent applied for and granted in 1935. This process, similarly as the Rogers process, embraces heating the cream with live steam to temperatures above 212° F.

The principal equipment consists of a surge tank with automatically controlled cream intake and outlet; a steam jet of prescribed design for injecting live steam in the cream between surge tank and jacketed vacuum pan with condenser; a vacuum pan with adjustable cream atomizer, vacuum pump, and a cream pump for discharging the treated cream from the bottom of the pan. The vacuum pan may also contain auxiliary compartments for additional steam and vacuum treatment of the cream.

The neutralized and preheated cream (temperature about 170° F.) enters the surge tanks from which it is pumped through a high temperature heating tube to the vacuum pan. The cream line leading from the surge tank is equipped with a steam injector, either of the Venturi type, or of other prescribed design that accomplishes thorough fusion of steam and cream, and that heats the cream to the desired temperature (200 to 250° F. or higher). Complete mixing with and action on the cream by the steam is further facilitated by the length of cream line between steam jet and entrance to vacuum pan. In the vacuum pan maintained at a high vacuum (about 25 to 26 inch), the cream is released through an adjustable distributor, that atomizes it into a fine mist, facilitating the expulsion of the heat-volatilized flavors and odors.

The sudden release of the heated cream into the vacuum chamber instantly lowers the temperature of the cream to the reduced boiling point corresponding with the high vacuum. The

jacket of the pan is heated to about 165° F. to prevent condensation of the odor-laden vapors and their return to the cream. The volatilized odors and vapors are voided through the condenser and treated cream is pumped from the bottom of the pan and cooled in the usual manner.

This process may also provide for additional steam treatment under vacuum by the presence of a series of compartments in the bottom of the pan, each compartment being equipped with a steam distributing pipe, and an overflow into the next compartment. In this case the atomizing jet through which the cream is released into the vacuum pan, throws the mist of cream against an inclined baffle from which the now fluid cream flows into the first compartment and overflows into each succeeding compartment toward the outlet of the pan. In each compartment it is again subjected to steam treatment under vacuum.

The Vacreator Vacuum Pasteurizer*.—This is a New Zealand development, and was evolved primarily for pasteurizing cream and eliminating feed and weed flavors. The inventor is H. Lamont Murray of Auckland, New Zealand. The Vacreator vacuum pasteurizer is enjoying wide application in butter manufacture in New Zealand and Australia. It has been introduced also into the United States, Canada, South Africa, Argentina and India. The Vacreator vacuum pasteurizer is covered by numerous U. S. Patents, and in its present form (1940) is constructed in stainless steel in three capacities rated at 2,500, 5,000, and 15,000 pounds maximum hourly cream flow, respectively. The machine combines pasteurization, flavor elimination and cooling in the one unit. Ejector condensors, supplied with water at the required pressure, create the vacua and provide the means for voiding the vapors and gases.

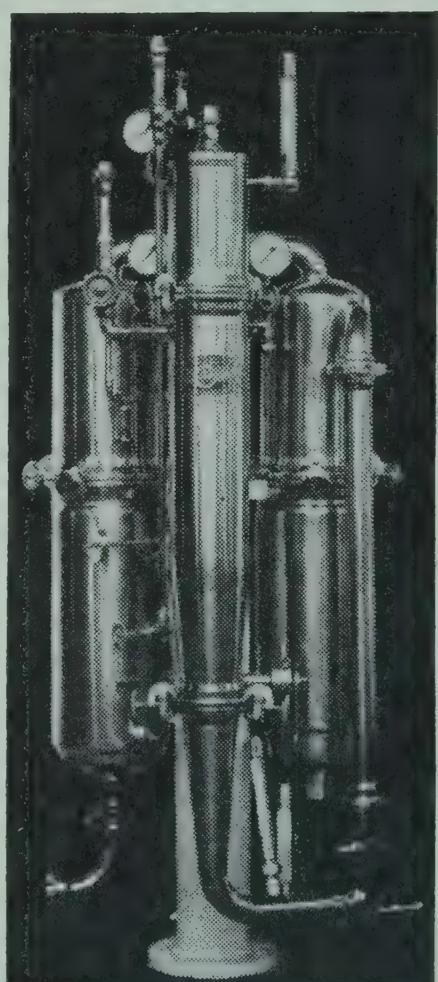


Fig. 53. Vacreator vacuum pasteurizer
Courtesy of F. S. Board, Corvallis, Oregon

*"VACREATOR" is the registered trade mark designating the Murray Vacuum Pasteurizers.

On its journey through the unit the cream is subjected to three successive stages of vacuum. In the pasteurizing section from 11 to 6½ inches (190° to 200° F.) are maintained. In the second or intermediate chamber 20 to 15 inches (162° to 179° F.) are carried. An equilibrium or semi-automatic vacuum control valve is placed between the two. The highest vacuum, about 28 inches (101° F.), is maintained in the third chamber or vacuum cooling section.

The raw cream, neutralized if necessary, may be slightly warmed or fed cold to the machine. It enters the pasteurizing cylinder at the top through a float valve. A constant amount of steam flows into this cylinder where a regulated low vacuum is maintained thus reducing the steam temperature. Upon entering the top of this cylinder the cream is caught in a spray pan from which it falls by gravity in a fine shower through the expanded steam and becomes instantly heated to the pasteurizing temperature, usually 190° to 200° F. The fine dispersion of the cream and its intimate commingling with the steam causes the cream to reach its peak temperature instantly (in one second), and to reach the bottom of the pasteurizing cylinder in an evenly heated state.

From the pasteurizing section the hot vaporous cream together with a regulated amount of excess steam then passes through the equilibrium valve, where, in the uptake pipe leading to the intermediate chamber, the excess steam is used to further intensify vaporization. Upon entering this zone of higher vacuum 20-15 inches, the hot cream conforms to the lower boiling point 162° to 179° F., its excess heat being quickly consumed in providing latent heat of vaporization. The cyclonic entry of the cream carries it around the walls of the chamber, thus separating vapors and gases from the liquid portion. The vapors and gases are expelled through the ejector condenser while the cream flows in a film down the chamber walls. A water-cooled jacket assists in rendering the cream vapor-free at the intermediate outlet valve.

The cream, at a temperature of from 162° to 179° F., now enters the zone of high vacuum (approximately 28 inches) of the vacuum cooling section. Entry to this chamber is by way of a second uptake pipe tangentially connected at the top. Here ebullition occurs, vapors are produced and carried off by the ejector condenser and the cream temperature is reduced to the

still lower boiling point (about 100° F.) corresponding to the high vacuum maintained. A second water jacket assists in rendering the cream vapor-free as it gravitates to the outlet. A 3-stage centrifugal pump then discharges the cream for final cooling in the usual manner. The entire cycle of treatment occupies not more than from 10 to 20 seconds according to the size of the machine in use.

The steam condensate in the pasteurizing phase dilutes the cream in proportion to the difference between the temperature of the untreated cream and the pasteurizing temperature employed and will usually fall between 8 and 12 per cent at this stage. Subsequent evaporation as the cream passes on through the higher vacua will reduce this to from 3 to 0 per cent. If the temperature of the untreated cream entering the machine is a few degrees higher than the temperature of the cream as it leaves the machine, no condensate will remain in the cream and the cream will not be increased in volume.

The Volatiliser.—The Volatiliser was designed and is manufactured by the Australian firm James Bell Machinery Proprietary Limited. The unit consists of a steam injection flash pasteurizer and a high-vacuum retort (vacuum pan). The pasteurizer is constructed of stainless steel. The cream enters the pasteurizer at the top where it intermingles with jets of direct steam. The cream is heated progressively, under steam pressure, as it flows over a series of stainless steel plates in a thin film, to a uniform temperature of 185° F. or higher. The discharge from the pasteurizer is regulated by a float-controlled valve, thus maintaining the desired steam pressure while a high vacuum is existing in the volatilizing chamber.

The vacuum pan is constructed of glass-coated steel. It is equipped with a rotating header of multiple, tangential cream-distributing tubes, a condenser with wet vacuum pump capable of maintaining a 27 to 28 inch vacuum, and a positive centrifugal cream discharge pump. The cream from the pasteurizer enters the vacuum pan at the top through the cream discharge tubes. Its release into the high vacuum pan causes it to form a fine mist which impinges against the sides of the pan and flows down over the glass-coated surface in a thin film. The escaping vapors and volatilized products are voided through the condenser and the high vacuum (27 to 28 inches) lowers the temperature of

the cream to approximately 101° F. The treated cream discharges from the vacuum pan at the bottom by means of a special, positive-action centrifugal pump.

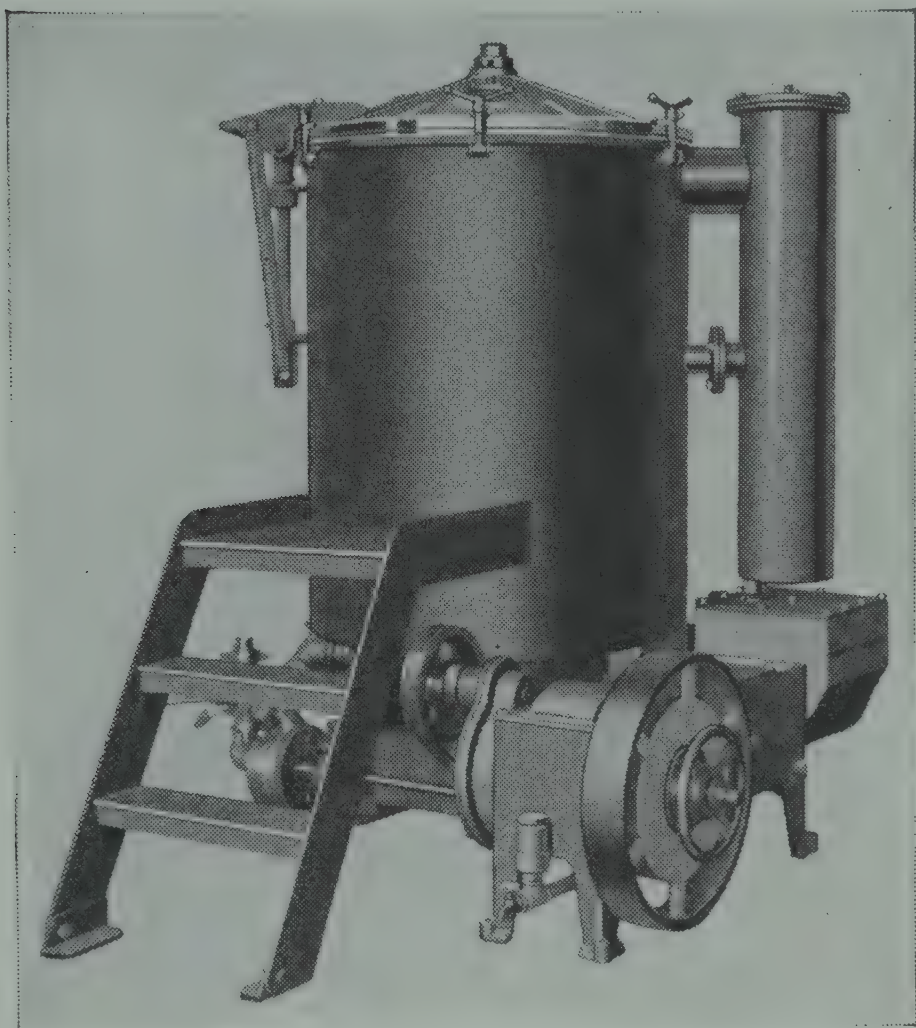


Fig. 54. The Volatiliser
Courtesy of James Bell Machinery Proprietary Limited

MERITS OF STEAM INJECTION-VACUUM TREATMENT

Heating with "Live Steam."—The first important step in the process of eliminating flavors and odors from cream has to do with volatilization of the objectionable flavors present, for it is only when converted into volatile form, that their expulsion is physically possible. In the operation of each of the cream-treating units described in the foregoing paragraphs, the cream is heated by injection of "live steam." It was, in fact, not until heating with "live steam" was adopted, that efficient flavor removal by the continuous-flow method became possible.

By reason of the intense impingement of the steam upon the cream and the intimate intermingling of the particles of steam and cream, made possible by direct steam injection, heat transfer is instantaneous, the cream reaches the desired temperature practically immediately, and exposure to the heat is momentary only. In the absence of air and of quality-jeopardizing metal

heating surfaces, the cream can be heated to relatively high temperatures without damage to its flavor.

The higher temperatures and the resulting fine dispersion hasten volatilization and extend the range of off-flavors that will respond to the volatilizing treatment. Volatilization is further assisted by the inevitable dilution of the cream with steam condensate.

Aside from the beneficial acceleration of the volatilization of objectionable flavors, the heating of the cream with "live steam" has the further advantage of fuel economy, utilizing every heat unit contained in the steam.

The method or manner of injecting "live steam" into the cream varies with different designs of machines and different processes. The steam injector may be of the Pemberthy or McDaniels type of steam nozzle, or it may be constructed according to the principle of the Venturi constricted tube injector, or it may consist of one or more plain-bore, cone-shaped nozzles with or without insulating jacket, or the nozzle may have a plurality of fine perforations, or slots, bored at the desired angle, usually at an angle of about 30°, blasting needle-like jets of steam into the cream, either concurrent with, or counter-current to the flow of cream, or both. The exact type of nozzle is largely a matter of personal preference. The really important feature that determines efficiency of operation is that the arrangement of installation be such, as to provide facilities for maximum dispersion, impingement and intermingling of the steam with every particle of the cream, and to accomplish this action before the cream-steam mixture is released into the vacuum. This is essential, not only with reference to volatilization of off-flavors, but also to insure maximum germ-killing efficiency.

Vacuum Treatment.—The second and final stage in this system of flavor removal has to do with the expulsion of the flavors and odors that have been made volatile by the heat treatment. For maximum efficiency prompt removal from the cream of the volatilized substances is indispensable. Delayed expulsion causes their re-absorption by the cream, thus forfeiting much of the benefit accomplished by the volatilizing effect of the heat treatment.

The rapidity and completeness of elimination of the volatilized flavors contained in the cream depends primarily on the

size of the cream particles. The finer the division, the smaller the particles and the larger the exposed surface area, the easier it is for the volatile substances to escape.

Releasing the heated cream into a high vacuum subjects it to partial atomization and vaporization, due to its lower boiling point in the reduced pressure of the vacuum chamber. The division and dispersion of the cream particles to a more or less mist-like state is further enhanced by introducing the cream into the vacuum chamber through a suitable spraying device, with small discharge ports, such as multiples of spray nozzles, similar to those used in spray-drying dairy products, or slotted distributor heads with or without adjustable ports. The fineness of cream spray produced depends on the size of the orifices through which the cream enters the vacuum chamber, the pressure on the cream, and the inches of vacuum into which it is released.

Elimination from the cream, of the substances that have been made volatile by the steam treatment is further facilitated by the diluted condition of the cream (due to the presence of steam condensate), and by the rapid evaporation of this extraneous water from the finely dispersed cream in the vacuum chamber, the escaping vapors carrying with them volatile essences and gases.

The prompt cooling of the cream to harmless temperatures (usually below 150° F.) corresponding to the lower boiling point in the vacuum chamber, protect the cream against the flavor-damaging effect of prolonged exposure to high temperature. The treated cream and resulting butter are, in fact, remarkably free from objectionable cooked flavor.

EFFICIENCY OF STEAM INJECTION-VACUUM TREATMENT IN COMMERCIAL BUTTER MANUFACTURE

Effect on Flavor.—Heating cream with "live steam" to temperatures above those of ordinary pasteurization, followed by vacuum treatment, has proven of distinct help in efforts to eliminate objectionable feed- and weed-flavors, as well as some of the minor age flavor defects of lesser intensity. To that extent this treatment does accomplish positive cream improvement.

This treatment does not, however, restore stale, fermented cream that is pronouncedly cheesy, yeasty, tallowy, rancid, putrid, metallic, etc., to its original state of freshness. It will not remove the type of flavor defects, due to either bacterial or

chemical action, that have changed or deprived the constituents of the cream of their natural character. It will not make Grade I butter from stale, fermented Grade II cream.

Experience has further demonstrated that fresh, sweet cream responds more readily to such treatment than stale cream and cream that has been allowed to sour. Stale or sour cream, or both, requires more severe treatment to free it from volatilizable, intense weed flavors, such as onion, garlic, French weed, etc., than does fresh, sweet cream. These facts have been observed by the author[13] over a period of years. Similar observations were reported by Combs and Coulter.[14]

It is probable, though not experimentally proven, that in stale cream the fusion of the objectionable flavor essences with the constituents of the cream, especially with the butter fat, has become more intimate and more permanent than it exists in fresh cream. In the case of sour cream, even when neutralized, the particle size of the casein has become larger due to the curdling action of the acid. The larger casein particles lock up more of the butter fat, rendering the flavor essences contained therein less accessible to the agencies of volatilization and of expulsion.

Likewise, intense weed flavors, such as onion, garlic, French weed, "peppergrass" and the like, require higher temperatures and more severe intermingling of cream and steam for volatilization, and a finer dispersion of the cream particles, for complete removal, than do slight feed flavors.

The choice of treatment that will yield the most efficient performance must take into consideration, therefore, the purpose for which the machine was designed and the type of cream for which it is intended to be used. Thus, for instance, when deodorizing for the purpose of eliminating slight feed flavors from fresh, sweet cream, with a view of raising the score from say 92.5 points to a full 93 score or better, heat treatment at high temperatures, such as above 212° F., is neither contemplated, nor necessary, nor even desirable. Nor should a deodorizer that has been designed for this purpose be expected to accomplish the complete removal of intense weed flavors from cream of mediocre quality.

On the other hand, "deodorization" of stale or sour cream that is heavily impregnated with the flavors and odors of such obnoxious weeds as onion, garlic, French weed, or so-called

peppergrass, etc., makes indispensable the use of high temperature treatment, maximum impingement of steam upon the cream and such intermingling, as will yield the greatest possible dispersion and division of the particles of cream.

The above facts are part and parcel of the experience of those who have concentrated their efforts on eliminating off-flavors from cream of good and poor quality in the routine of commercial butter manufacture. They are likewise supported by the recent experimental findings of Wilster[12] who compared the results of vat pasteurization at 155° F. for 30 minutes with steam injection-vacuum treatment, using the Vacreator Vacuum Pasteurizer. Wilster's investigation embraced 86 sets of comparisons extending over a period of one year. Vacreation increased the average score of butter when fresh 0.83 point. The greatest improvement took place during April, May and June. The scores of butter made during these months averaged 1.27, 1.21 and 1.31 points, respectively, higher for vacreated cream than for vat pasteurized cream. Wilster reported that "the improvement in quality was due to freeing the cream during vacreation, particularly during the spring and summer months, from feed, weed and certain loosely bound extraneous flavors. Inferior cream was not improved materially." The butter made from vacreated cream showed the least deterioration during storage. Vacreation was effective in eliminating onion and scale weed flavor from cream that was badly tainted with these weed flavors. The vacreator experiments of Fabricius[15] and of Brown[16] yielded similar flavor improvement.

Riddet[18] (New Zealand) further reported that "recently we have been doing work with it (the vacreator) in attempts to remove a very tenacious feed taint imparted to cream by a weed belonging to the natural order of cruciferae. The plant in question is Coronus didymus, locally called 'land cress.' Ordinary methods of pasteurization tend to accentuate the flavor in butter affected with this taint, and I am pleased to say that the Vacreator has been very effective in removing it."

Effect on Body of Butter.—Experience in commercial butter manufacture over a period of years has demonstrated that, neither the heating of the cream with live steam to high temperatures (as high as 300° F.), nor atomization in the vacuum, nor the combined and successive steam and vacuum treatment,

have any noticeable or objectionable effect on the body and texture of the resulting butter. In some cases, in fact, a distinct improvement in texture has been observed. Both, Wilster[12] and Fabricius[15] observed an improved body of butter from Vacreator treatment, and Fabricius reported that this treatment appeared to eliminate the sticky and crumbly defect of winter butter. This is the case with treatment by the continuous process. Prolonged treatment by the batch system, such as when recirculating the heated cream through the vacuum chamber, however, does have a tendency toward a less clear body and a less smooth texture, and toward a mealy character.

Effect on Fat Losses.—The tendency of steam injection vacuum treatment of cream for the removal of objectionable flavors lies in the direction of increasing the buttermilk test. It was shown in Chapter XI, under "Effect of Pasteurization on Fat Losses" that such heat treatment tends to increase fat losses. McDowall[4] of New Zealand reported an average buttermilk test of 0.946% for vacreated cream as against 0.689% for pasteurized cream. The results of Fabricius[15] show an average increase of 0.2% in the buttermilk test, and a 0.5% increase of the total fat lost for vacreation over vat pasteurization.

In steam injection methods that employ higher temperatures the fat losses appear still greater. Thus Roberts and coworkers,[17] experimenting with steam injection and heating to 260° F., followed by vacuum treatment, reported buttermilk tests ranging from 1.0 to 1.7% fat.

Some fat losses occur also, in any cream improvement process that involves vacuum treatment, due to entrainment losses of cream through the condenser. These entrainment losses vary considerably with design of machine. The nature of operation of the unit likewise has some effect. Considerable progress has been made in mechanical improvement of equipment, in efforts to reduce entrainment losses to the minimum, such as by installation of ingenious baffle devices and arrangements in the vacuum chamber and between it and the condenser, etc. While these improvements are of material assistance, they do not prevent completely all entrainment losses.

OTHER PROCESSES OF CREAM IMPROVEMENT

Cream Improvement by Re-Separation.—The theory of cream improvement by re-separation is based on the assump-

tion, that many of the off-flavors contained in cream are associated with the non-fatty constituents of the cream, particularly the curd, and that the elimination from the cream of a large portion of its serum by re-separation, will remove these objectionable flavors and improve the quality of the butter.

The process which was used in numerous creameries of the middle western states of this country during the years 1927-1933, consisted essentially of neutralizing the cream to a very low point, either to neutrality or lower. A soda neutralizer (mostly sodium hydroxide) was used, in order to convert the curdy material into a state of semi-solution. This appeared necessary in order to prevent rapid filling and clogging of the separator bowl. The neutralized cream was then heated to about 125 to 140° F., usually with direct steam, and the cream was passed through a cream separator with a modified top dish in the bowl and with the cream screw adjusted to yield a high-fat cream. The re-separated cream, averaging approximately 70 to 80% fat, was diluted with skim milk and in some cases part skim milk and part water, so that when mixed with a considerable portion of unseparated cream, the fat content of the mixture would be below 40%. The diluted cream was then handled in the usual way.

As a whole, the results proved disappointing, and the improvement in flavor, if there was any, did not justify the expense of re-separation. With the possible exception of bitter flavor, resulting from certain weeds, such as bitterweed, re-separation did not eliminate feed or weed flavors, nor old, stale cream flavors, such as cheesy, tallowy, rancid, metallic. The major advantage of re-separation was that it made possible the use of slightly more cream of intermediate grade with Grade I. This was accomplished by so adjusting the cream grading standard, as to first set aside all Grade I cream, then regrade the remainder, culling out all cream scoring 88.5 or below. This then left the intermediate grade, scoring above 88.5 and below 90. By re-separating this intermediate grade it was possible, when mixing an amount of separated oil (about 800 to 1000 lbs.) equivalent to one churning of cream of intermediate grade, with about three churnings of unseparated Grade I cream, to still maintain the quality of No. 1 butter (90 points). The oil from the re-separated intermediate grade did not improve the quality of Grade I, but it did not lower it sufficiently to depreciate its

market value. Neither Grade I cream nor Grade II cream was improved by re-separation.

The fat losses in the tailings of re-separation averaged between .05 and .3%, although occasional losses of 1.0% or over did occur. The tailings were a total loss. The slight improvement in quality of finished product failed to justify the considerable expense involved, such as initial cost and expense of up-keep of the extra equipment required, the cost of the skim milk and the added cost of operation. As a result, the wave of cream improvement by re-separation was short-lived, and the process is now no longer given serious consideration by the industry.

Cream Improvement by Successive Re-Separation and Washing of Cream.—Much experimental work has been done in efforts to secure more positive cream improvement from re-separation, by washing (diluting the cream before or after re-separation, or both), and by successive repetitions of the treatment. The washing or diluting of the cream was done with either water or skim milk, usually using skim milk for the final dilution.

Such treatment obviously makes for a somewhat more complete removal of the non-fatty constituents and of decomposition products from the stale, fermented cream. In addition, their replacement by the serum solids of fresh skim milk, further assists in making this treatment somewhat more effective than re-separation alone. Yet, even these intensified efforts have yielded only slight improvement in quality, and the added cost of operation, together with the accumulated fat losses of repeated re-separations, render this type of cream improvement effort economically prohibitive and impracticable.

The "Elact" Process of Cream Improvement.—This process consists of treating cream with electrically de-acidified skim milk. Within recent years the "Elact" process of electrically de-acidifying market milk has gained considerable recognition and is reported to be in successful commercial use in certain European milk plants.

These results have led to experiments by Gratz[5] and others, in efforts to apply the process to the treatment of sour cream in butter manufacture. The method advocated contemplates the washing, or dilution, of the cream with electrically de-acidified

skim milk, preceded or followed, or both, by centrifugal re-separation.

The apparatus for electrical de-acidification of milk and skim milk was developed by the Elact Electrical Apparatus Co. of Vienna, Austria. It consists essentially of a tubular container constructed of glass or earthenware. It contains a series of electrodes, properly spaced. The bottom electrode is connected with the positive pole and the top electrode with the negative pole of the A.C. electric current. The milk enters at the bottom, passes through the series of electrodes and leaves at the top of the container.

In this process the milk or skim milk is de-acidified (neutralized) by the electric current. In the case of cream the treatment is indirect. The cream itself does not pass through the electric de-acidifier, but is washed (diluted) with electrically de-acidified skim milk. The advantages claimed by the use of electrically de-acidified skim milk for washing or diluting the cream in connection with re-separation, are that the same skim milk can be used several times over, thus reducing the volume of fresh skim milk required and minimizing the fat losses of repeated re-separations. Gratz reports that the cream improvement resulting from the use of electrically de-acidified skim milk is very marked. Quoting the results of a trial made on a commercial scale by the Hungarian Provincial Central Dairy in Budapest, of which concern he is the technical advisor, the butter resulting from the "Elact" cream treatment scored 7 points out of a possible 9 points, while the control lots scored only 4 points.

Cream Improvement by the Aerofuge Process.—The equipment and method of the Aerofuge process were developed by the Omaha Cold Storage Co., Omaha, Nebr. The machine consists of a laundry-type centrifuge with large diameter bowl (approximately 3 ft.) but with no perforations in the bowl wall. In this case the underlying purpose is centered on the elimination of extraneous matter and of curdy material, without otherwise changing the original composition and per cent of fat of the cream.

The cream is heated by direct steam injectors to a high temperature (approximately 212-220° F.), on its way to the centrifuge. The heated cream is carried to near the bottom of

the revolving bowl and overflows over its top in the form of a spray into the outer casing of the bowl, from where it discharges into a surge tank, and is cooled in the usual manner. Due to the centrifugal force generated by the high speed of the revolving bowl, the cream deposits on the bowl wall a large amount of curdy material and such extraneous impurities as it may contain.

The top of the centrifuge is hooded. The vapors from the hot cream spray that issues from the bowl periphery and discharges into the space between bowl casing and revolving bowl, rise up into this hood and are expelled to the outside by a powerful suction fan.

This machine was originally designed for the purpose of eliminating extraneous matter from cream. Judging from the amount and character of the deposit on the bowl wall, it appears to accomplish this purpose. The expulsion, by forced draft, of the vapors arising from the centrifugalized cream spray of the overflowing bowl, is of some assistance in the removal of objectionable volatile products.

CREAM IMPROVEMENT BY THE USE OF CHEMICALS

Alkalies.—The use of alkalies in butter manufacture is limited to the neutralization of sour cream, see Chapter X on "Neutralization." Alkalies are incapable of removing from cream intense off-flavors and odors. When used to neutralize cream to a relatively low point of acidity, they are of some assistance in minimizing the intensity of certain off-flavors, such as metallic flavors. Neutralization to a low point has the further advantage of making possible considerable flavor-improving action in the cream by the subsequent use of a good starter, without raising the churning acidity above the critical point with reference to age deterioration of the butter due to flavor damaging chemical reaction.

Chlorine Compounds.—Chlorine disinfectants, added to the cream before pasteurization, have been found to be capable of minimizing off-flavors, either by partial elimination or by covering up the objectionable flavor, particularly in the case of obnoxious weed flavors.

Of this group of chemicals the Chloramine-T type of chlorine products has proved most effective. Their use does not

accomplish a general improvement of the quality of the cream, however. Their justification is confined to their assistance in improving the marketable properties of butter made from cream that is impregnated with flavors of obnoxious weeds, such as wild onion, garlic, French weed, etc., and even for this purpose they are of limited benefit only. Their mention in the present discussion refers to the fact that they are being used to some extent. They cannot be recommended as a desirable means of cream improvement. When used in amounts sufficient to accomplish elimination of the objectionable weed flavor, the chlorine taint is usually so pronounced, as to jeopardize the salability of the resulting butter. Similar observations were also reported by Combs and Coulter.[14]

Hydrogen Peroxide.—The use of hydrogen peroxide in combination with heat treatment of market milk was originally recommended by Budde, who introduced the process known in Europe as "Buddizing."

Experiments, by the author, on the effect of the use of hydrogen peroxide on cream yielded a slight freshening of the flavor of the butter made from cream so treated. Generally speaking, the results were largely negative and failed to justify the expense of such treatment.

Listerine.—Attempts to eliminate onion flavor and similar off-flavors have demonstrated that the addition to garlic cream, of 1% of a .5% solution of listerine in water, produced butter with very slight garlic flavor, while the butter of the control churnings possessed a pronounced garlic flavor and odor. The butter made from the treated cream, however, showed evidence of listerine flavor. Experiments by Combs and Coulter[14] yielded similar results.

Legal Restrictions in U. S. A.—With the exception of harmless alkalies employed for the neutralization of sour cream, the use of all chemical preservatives in milk products is prohibited by law in the United States, as well as in the majority of dairy countries throughout the world.

Treating Cream with Carbon Dioxide Gas.—Attempts have been made to improve the flavor of cream and butter by churning the cream and working the butter in an atmosphere of carbon dioxide. A process to this effect, covered by U. S. Patent

No. 1,384,318 was granted to Paul Heath. The procedure consists of first loading the churn with cream. Carbon dioxide is then run through the cream from the bottom of the churn until a pungent odor escapes from the open vent. The churn vent is then closed and the churning operation started. The churn may be given a second charge of carbon dioxide before the butter breaks. The washwater may be carbonated in the same manner and the churn may be recharged with carbon dioxide again at the beginning of the working process. The carbonating of the washwater, and of the butter during working, is not included in the Heath patent.

It was shown experimentally by Hunziker,[6,7] Sherwood and Martin,[8] and Prucha, et al.,[9] that the carbonating of cream for buttermaking is incapable of removing undesirable flavors, and odors from cream and of improving the flavor and keeping quality of butter.

More recently (1936-37) a process of cream improvement by churning, washing and working butter in CO_2 under pressure of four to five atmospheres (approximately 50 to 70 lbs. pressure) was advocated by Senn[10]. This process was developed by the Swiss Engineer Feremutsch, and patented as per U. S. patent letter No. 2,007,043. It involves the use of a pressure churn with revolving dasher-agitator, geared to approximately 800 R.P.M. The claims for this process embrace such items as improvement of flavor and keeping quality of butter, shortening of churning period to about one minute, and low buttermilk tests.

Neither equipment nor process have progressed beyond the experimental stage. Demonstrations by Senn in the Blue Valley Research Laboratory in co-operation with Hunziker, Cordes and Ihde[11] failed to yield satisfactory uniformity of composition of butter, or exhaustiveness of churning. The buttermilk tests ranged from 1.42 to 2.67% fat, averaging 2.02%. These results were undoubtedly largely due to the mechanical inadequacy of the experimental churn.

The butter did churn out in from one to two minutes. Churnings in the same churn in the absence of CO_2, however, yielded the same churning time as churnings made under CO_2 pressure, indicating that the factor responsible for the short churning period is not the CO_2 under pressure, but the nature and high speed of agitation.

The CO_2 treatment, while it did not remove off-flavors pres-

ent in the cream, had a pleasing, freshening effect on the flavor of the butter. The CO_2 churnings averaged .16 points higher in flavor score than the control churnings. In storage the CO_2 churnings retained the freshness of flavor somewhat better than the control churnings. This was particularly noticeable in churnings of unsalted butter. The improvement in flavor was not sufficient, however, to raise the quality of the butter to the next higher market grade.

In view of the very limited improvement in quality, and of the fact that the development of equipment suitable for churning in an atmosphere of CO_2 under pressure would involve much experimenting and an unavoidably heavy, undetermined financial outlay, without even reasonable assurance of success in making the process commercially feasible, further consideration of this method of CO_2 treatment as a means to accomplish cream improvement, does not appear justifiable.

Economic and Ethical Aspect of Cream Improvement in the Factory.—In general, the addition of methods and processes to the routine of manufacture add to the operating cost and raise the price which the consumer must pay for butter. In order to justify this extra cost, the method must either give added protection to the health of the consumer, or it must serve to prevent costly losses of butter fat or losses due to avoidable spoilage, or it must provide improvement in quality that will increase the market value of the butter sufficiently to offset the added cost.

The legitimate treatment of cream of good quality for the removal of feed and weed flavors and of certain unavoidable extraneous flavors that it may contain, is undeniably justifiable, both economically and ethically. It assists in protecting the butter made from cream containing these off-flavors, against heavy penalties by the market, and it raises its market value to that which its intrinsic quality merits. It is economically sound, and ethically above reproach.

In the case of cream of poor quality, such as results from lack of sanitation and care on the farm, and from excessive age, causing the cream to be impregnated with fermentation products and their off flavors, such as cheesy, tallowy, rancid, metallic or other flavor defects resulting from age deterioration, attempts at flavor removal by any means short of separating the pure butter

oil and "renovating" it, are usually a waste of effort. The by-products of decomposition and their objectionable flavors remain in the cream and reappear in the butter. No legitimate process of cream improvement, now known and available, is capable of eliminating them satisfactorily. Such cream fails to respond to any process or treatment sufficiently to justify the added cost of operation, or that will satisfy the accepted standard of ethics relating to food products. Constructive quality improvement of this type of cream must come through prevention that means better care in production and handling on the farm and in transit and more frequent delivery to the factory, supported by the consistent and courageous adherence to a rational program of cream grading and quality-paying on the part of the creamery.

REFERENCES

1. AYRES, S. H., and JOHNSON, W. F., U. S. Dept. Agr. Farmers' Bul. 608, (1914).
2. HUNZIKER, O. F., J. D. Sc. VIII, *2*, (1925).
3. GRINDROD, GEO., Information by correspondence, (1939).
4. McDOWALL, F. H., N. Z. Dairy Res. Inst. Publ. 110, (1938).
5. GRATZ, O., Le Lait XIV, 132, 145, (1934).
6. HUNZIKER, O. F., J. D. Sc. VII, *5*, (1924).
7. HUNZIKER, O. F., N. Y. Prod. Rev. and Am. Cry *60*, 2, May 13, (1925).
8. SHERWOOD, F. F., and MARTIN, F. G., Ia. Agr. Expt. Sta. Res. Bul. 95, (1926).
9. PRUCHA, M. J., BRANNON, J. M., and RUEHE, H. A., J. D. Sc. VIII, *4*, (1925).
10. SENN, JAS., Blue Valley Res. Labs. Expts. (not publ.), (1936-37).
11. HUNZIKER, O. F., CORDES, W. A., and IHDE, A., Blue Valley Res. Labs. (not publ.) (1936-37).
12. WILSTER, G. H., Ore. Agr. Expt. Sta. Bul. 368, 1940.
13. HUNZIKER, O. F., Blue Valley Res. Labs., not publ. (1922-39).
14. COMBS, W. B., and COULTER, T. S., Abstr. J. D. Sc. XX, 458. (1937).
15. FABRICIUS, N. E., Ia. State Coll. by Correspondence, (1940).
16. BROWN, R. W., Univ. Manitoba, by Correspondence, (1940).
17. ROBERTS, W. M., COULTER, S. T., and COMBS, W. B., J. D. Sc. XXIII, (1940).
18. RIDDET, WM., Dir. Dairy Res. Inst., N. Z. by Correspondence, (1940).

CHAPTER XIII

STARTERS AND STARTER MAKING

Definition.—By starter, such as is used in the manufacture of butter, is meant a bacterial culture in milk or other fluid milk product, that is added to cream or butter for the purpose of accentuating in the butter the desired flavor and aroma.

Formerly starter was correctly defined as a clean-flavored batch of sour milk. Today a good starter is more adequately defined as a culture in milk or other fluid milk product, of selected bacteria capable of developing in milk, cream and butter the desired flavor and aroma.

Kinds of Starters.—On the basis of origin and method of preparation, starters may be conveniently grouped in two main classes; namely, natural starters, and pure culture starters.

Natural Starters.—Natural starters, constituted the earliest attempts to control the development of flavor in cream for butter manufacture. They usually consisted of spontaneously soured, clean-flavored milk or skimmilk, or of sour cream, or buttermilk from a previous churning of good butter. Their bacterial flora is variable and their results are correspondingly uncertain. The practice of using natural starters predates the study and use of cultures prepared with selected bacteria by over a quarter of a century, and it continued in some creameries for many years after the introduction of pure cultures in the form of commercial butter cultures.

Pure Culture Starters.—Pure culture starters are cultures, the bacterial flora of which is made up exclusively of selected bacteria. The progressive results of research efforts extending over a period of half a century have conclusively established the fact, that the principal agencies responsible for the desired aroma and flavor characteristic of butter of fine quality, are the neutral flavor substances of diacetyl and its mother substance acetylmethylcarbinol (acetoin), together with carbon dioxide and certain volatile acids of which acetic and propionic acid appear to be the most important.

These flavor and aroma products in starter culture are preeminently products of citric acid fermentation which is brought about by certain species of citric acid-fermenting bacteria in associative action with certain species of lactose-fermenting bacteria, usually called lactic acid bacteria.

Of the lactic acid bacteria, S. lactis and S. cremoris are the recognized types of species for starter cultures. Of the citric acid-fermenting bacteria S. citrovorus and S. paracitrovorus (Hammer) and Betacoccus cremoris (Orla-Jensen) are the typical organisms. The principal difference between S. citrovorus and S. paracitrovorus is that the former produces no lactic acid, while the latter produces Levulo-rotary lactic acid, whereas S. lactis and Betacoccus cremoris yield dextro-rotary lactic acid. The name Betacoccus cremoris is based on the ability of the organism to produce lactic acid, which places it into the genus Betacoccus of the Orla-Jensen System of lactic acid streptococci.

In order to accomplish the development of the desired butter aroma and flavor, both types of organisms, the lactic acid bacteria and the citric acid-fermenting, flavor-producing bacteria must be present in the starter culture. Neither type of organisms alone is capable of producing the characteristic butter aroma and flavor.

HISTORY AND DEVELOPMENT OF STARTER CULTURES

Early History.—The bacteriological study of butter was initiated by the eminent Danish bacteriologist, V. Storch[3] in 1884, and in 1888 he introduced his pure cultures of lactic acid bacteria for use in the souring and ripening of pasteurized cream. According to Orla-Jensen[2] the first commercial starter cultures were provided for creamery use in 1890. Hansen[3] reports that their adoption in Denmark gained rapidly, and that by the year 1897, 802 of the 866 creameries then in operation in Denmark used them.

Simultaneously with Storch's discoveries the use of pure cultures for cream ripening was studied by Weigmann[4] in Germany, and by Conn[5] in the United States. In North Germany the system adopted in Denmark, of pasteurizing the milk or cream and ripening the cream with pure cultures of lactic acid bacteria spread rapidly and soon enjoyed fairly general acceptance and use among North German creameries.

In this country H. W. Conn,[5] the eminent biologist of Wesleyan University and of the Connecticut Agricultural Experiment Station, made extensive studies and independent discoveries regarding the possibilities and the use of butter cultures. As early as 1889 he began the publication of a series of bulletins on cream ripening and pure culture starters, and his labors played an important role in the initial introduction and use of commercial starter cultures in America during the years 1890 to 1900.[6]

Progress with pure starter cultures in American creameries was slow at first. Among the principal reasons for the industry's reluctance to use pure culture starters were the facts that the majority of buttermakers were not in condition to pasteurize their cream, and that the American consumer demanded a higher flavored butter than resulted from the use of the then available commercial cultures of lactic acid bacteria, used in connection with pasteurized cream.

As the merits of pasteurization of cream for buttermaking became more fully recognized, and as the possibilities of the proper use of pure culture starters became more generally known and appreciated, the initial objections gradually yielded to the more general adoption of the use of commercially prepared starter cultures. While even today the economic merits of making butter from cream ripened with pure culture starters are still a controversial issue, and while the use of pure culture starters is by no means universal in American creameries, it is now fully recognized that the proper ripening of efficiently pasteurized cream, with starter cultures of selected lactic acid-producing and citric acid-fermenting bacteria, accentuates the desired butter aroma and flavor, and makes for greater uniformity of flavor and aroma in butter.

Bacteriology of Pure Culture Starters.—It was early recognized by the great pioneers of starter cultures prepared from selected bacteria, that the problem of organisms involved and products formed is an exceedingly complex one, and that the typical result of a strictly pure culture of S. lactis is far from the desired flavor and aroma; that it is in fact a flat, acid, sour milk flavor.

Thus, Storch's trials in 1888 in which he supplied the cultures for use in the making of butter from pasteurized cream,

showed that the pure lactic acid cultures did not produce as fine flavored a butter as when using buttermilk from a churning of good butter for inoculation of the cream. Conn, as early as 1889, concluded that "the ripening of cream is a complex matter." In 1896 he pointed out that, while the acid is developed from the sugar of milk, the flavor probably comes from other sources. He held that acid and flavor should be considered separately and that aroma should be distinguished from flavor. Weigmann,[7] and McDonnell[8] found a variation of the products formed by acid-producing bacteria, they were inclined to attribute the production of aroma to several species of lactic acid bacteria, and believed that more than one species is necessary to produce a good starter. Later, in 1908, after much further study of and experience with starters, Weigmann[9] expressed his belief that a good starter should contain ferments of the type of Streptococcus lacticus and of the aroma type, and that the specified aroma is produced by several bacteria.

Starter Cultures Must Contain Lactic Acid Bacteria and Flavor Bacteria.—These early impressions and observations were clarified and definitely confirmed in 1917 to 1919 by the researches of Storch,[10] Hammer and Bailey,[11] Boekhout and Ott de Vries[12] and Orla-Jensen.[13] These investigators, independently and almost simultaneously, found and demonstrated that a good butter culture is not a pure culture of one single species of organisms.

Thus, Hammer,[14,15,16,17] found in commercial butter cultures not only the lactic acid producing S. lactis, but in addition, and associated with S. lactis, two associated organisms. He likewise discovered that citric acid is the primary source of the volatile acids formed in starter cultures by the organisms associated with S. lactis and he named the two closely related citric acid-fermenting organisms, S. citrovorus and S. paracitrovorus.

Flavor and Aroma Depend on Presence of Diacetyl.—Another important step forward in our knowledge of butter cultures and butter aroma was brought about by the discovery in 1928-29, on the part of the German chemists Schmalfuss,[18] and Schmalfuss and Barthmeyer,[19] and by the Dutch scientists Van Niel, Kluyver and Derx,[20] that diacetyl and its mother substance acetylmethylcarbinol (acetoin) are largely responsible for the aroma of fine butter made from ripened cream. Subsequent

studies by Michaelian, Farmer, and Hammer,[21] and other investigators, showed that the citric acid-fermenting S. citrovorus and S. paracitrovorus of Hammer, or Betacoccus creamoris (Orla-Jensen), when associated with the lactic acid producing S. lactis or S. cremoris, yield in addition to lactic acid, volatile acids, such as acetic and propionic, CO_2, and diacetyl (i.e., principally its mother substance, acetylmethylcarbinol from which diacetyl is believed to result through oxidation).

Michaelian and Hammer[22] reported that "their results indicate that the formation of diacetyl from acetoin in a butter culture is due to the activity of organisms rather than to a simple chemical oxidation," and they attribute this oxidation to the activity of the aroma organisms. Van Beynum,[23] as the result of independent research, also held that it is the aroma bacteria that are responsible for the production of diacetyl, but not as the result of oxidation of acetoin, but by oxidation of an intermediate product, probably acetaldehyde.

The work of Hammer, Stahley, Werkman and Michaelian[24] further indicates that the flavor-producing organisms may, under certain conditions, reduce acetylmethylcarbinol and diacetyl to 2, 3-butylene glycol. Thus, an abnormal development of the flavor type of bacteria in the starter culture may cause the dissipation of the initial products which they produced, causing a lack of the diacetyl character of flavor and giving the impression of an "over-ripe" condition.

Still more recently a new flavor-producing lactic streptococcus was isolated from spontaneously soured potato mash by Matuszewski et al.[25] These authors reported that this organism which they have named S. diacetilactis, unites the essential features of S. lactis and of S. citrovorus and S. paracitrovorus. It produces large amounts of both lactic acid, and of volatile and aroma products such as acetylmethylcarbinol (in the form of diacetyl), acetic acid and CO_2. However, Ritter and Nussbaumer[26] who experimented with cultures of S. diacetilactis reported that the flavor and aroma produced by these cultures was not quite equal to that of mixed cultures of acid organisms and aroma organisms, and that continued propagations showed a gradual decline of the desired, characteristic butter aroma and flavor.

Effect of Citric Acid Content on Intensity of Starter Flavor.

—Michaelian and Hammer[22] discovered that an increase of citric acid by addition of citric acid to the milk tended to increase volatile acidity and flavor products. They obtained similar results by the addition of other acids such as acetic acid, phosphoric acid and sulphuric acid, which suggests that those other acids assisted in the liberation of the citric acid from its salts, thus accelerating its breaking down. This assumption was further supported by their findings that when these other acids were added to milk from which the citric acid had previously been removed, there occurred no increase in the volatile acidity.

Fabricius and Hammer[27] found that generally, the addition of 0.15 per cent citric acid to the milk intended for culture, resulted in higher scoring butter than when no citric acid was used. Similar results of the addition of citric acid to starter or to cream (adding .2% citric acid) are reported by Templeton & Sommer[28,29] and by Templeton.[30] Vas and Csiszar[31] likewise emphasized the advantages of added citric acid or sodium citrate. They found that the addition of small amounts of citric acid (.06%) stimulated aroma production as much as larger amounts (.12 to .25%). While the addition of citric acid has proven effective in increasing the aroma products in most cases, there have occurred exceptions also, where this practice failed to yield satisfactory aroma and flavor, and where it was necessary to start with a new culture. Cordes[32] also reported somewhat negative results in that the addition of citric acid to milk with otherwise satisfactory solids content, failed to increase the intensity of the desired diacetyl type of flavor, and he suggested that the addition of citric acid to milk to be made into starter, should not be considered a cure-all for starter troubles, or as an insurance for satisfactory results.

ESSENTIAL REQUIREMENTS OF GOOD STARTER CULTURES

The essentials in the production of a good starter are ably discussed by Cordes.[32] They embrace the presence and proper balance of the right organisms; milk of good quality and of suitable chemical composition; dependable control of incubation as to rate of inoculation, temperature, time, and air supply; suitable utensils and equipment; and sanitation in handling.

Selected Bacteria.—The foregoing discussion showed that the neutral flavor substance diacetyl is the primary product

upon which depends, in a large measure, the desired aroma and flavor of a good starter, that the lactic acid that gives the starter its pleasant acid flavor is quantitatively the main product of fermentation, and that various other substances, such as volatile acids, principally acetic and propionic, and carbon dioxide, also enter into the combination of known products responsible for the characteristic butter aroma and flavor.

It has been further shown that the fermentation that yields these flavor and aroma products is not brought about by one single species of organisms, but requires the presence, in the starter culture, of at least two groups of bacteria, namely lactic acid bacteria of the type of S. lactis or S. cremoris, and citric acid-fermenting bacteria of the type of S. citrovorus, S. paracitrovorus, or Betacoccus cremoris.

A good starter culture, therefore, must contain lactic acid- and citric acid-fermenting species of bacteria and they must be present in suitable proportion. Hammer showed that under practical conditions S. lactis is present in much larger numbers than the citric acid-fermenting organisms. Both creamery and commercial cultures, often contain S. lactis in numbers amounting to 90% or more of the total flora and they seldom fall below 75%, leaving 25 to less than 19% of the flora made up from citric acid-fermenting organisms.

To the practical buttermaker the flavor and aroma of the starter, of the cream that has been ripened with it, and of the resulting butter and buttermilk, are dependable indices of the organisms he has in his starter culture and of their proper balance. Scientifically, the presence and activity of the flavor organisms is readily measured by the production of volatile acid or of acetoin + diacetyl, or both.

The volatile acidity is expressed in terms cubic centimeters of N/10 alkali solution required to neutralize the first liter of distillate resulting from distilling with steam 250 grams of the starter culture to which 15cc. N/1 H_2SO_4 has been added to liberate the volatile acids. Hammer[14] found good starters made from lactic acid bacteria and citric acid-fermenting organisms to range mostly from 30 to 40 cc. N/10 alkali.

The quantitative amount of acetoin + diacetyl is expressed in terms of millimeters of the nickel salt (nickel dimethylglyoximate), derived from 200 grams of starter culture. Of 91 cultures examined that showed satisfactory flavor and aroma

Hammer[21] recorded a range of from 10 to 46 mg. of nickel salt, while the maximum amount found in 41 cultures that lacked flavor and aroma was 7.4 mg. The results of Cordes[32] show the same general trend as to amounts of acetoin + diacetyl in Blue Valley Creamery Co. starter cultures, ranging from 30 to 58 mg. of nickel salt after holding at 40° F. for several days.

Source of Organisms.—Regarding the source of suitable organisms for assembling a good starter culture, Cordes[32] found good, clean-flavored, moderately sour cream, showing the desired character of starter flavor and aroma itself, a very satisfactory source of both types of bacteria. In the absence of facilities for bacteriological work in the creamery, most of the commercial starter cultures, and cultures supplied by State dairy schools, may be depended upon to provide the selected organisms essential for a good starter.

Quality of Starter Milk.—Milk of good quality is essential for the preparation of a good starter culture and a good starter. While efficient pasteurization will assist in minimizing defects of the raw material, a really good starter cannot be made unless the milk which is used, is fresh, clean, and unadulterated.

The successful production of the desired flavor and aroma in the starter precludes the presence of off-flavors in the milk itself. Feed and weed flavors, salty, bitter, rancid, or metallic flavors, all furnish a background, due to a variety of causes some of which are not as yet satisfactorily understood, that interfere with the proper functioning of those agencies and reactions that are responsible for the production of the true butter aroma substances.

The milk, in order to be suitable for starter culture purposes, must be sweet to taste and free from developed acidity. The natural acidity of fresh milk averages approximately .145 to .15%, although it may run considerably higher in isolated cases, especially in the case of individual cows. Generally speaking, however, when mixed herd milk arrives at the factory with a titratable acidity above .18%, it contains considerable developed acid, due to bacterial action. While still sweet to the taste of the average consumer, it is already in the early stages of souring. Such milk is no longer suitable for culture work. It usually will not respond to the type of fermentation that yields the flavor substances necessary for the flavor and aroma

typical of good butter culture. The diacetyl character fails to develop, the ripened culture lacks aroma and usually shows a flat, sour and cheesy-like flavor. Its use for ripening cream is of no benefit and may even be damaging to the flavor of the resulting butter.

Total Solids in Starter Milk.—The milk must have a normal total solids content. Other conditions being equal, milk containing from about 12 to 12.5% total solids appears to be best suited for the satisfactory functioning of the acid and flavor organisms. When the milk drops appreciably below 12% in total solids, it is usually difficult to bring the flavor and aroma of the starter up to the desired point. Acid production is retarded, coagulation is weak, and the taste remains flat, lacking in the typical flavor character desired. Milk that has been adulterated by the addition of extraneous water is unsuitable for starter work. In the case of an excessively high total solids content, there is danger of over-development of the flavor organisms, with heavy production of CO_2, and the tendency of a dissipation of the diacetyl character that may lead to the appearance of metallic flavor. These facts emphasize the wisdom of taking lactometer readings on milk intended for starter, particularly at times of unsatisfactory flavor development. Readings much above or below 32 (in case of Quevenne at 60° F.) suggest too high or too low total solids content. In such case a change of milk supply is usually the most effective means to improve the character of the resulting starter.

Citric Acid Content of Starter Milk.—The citric acid content of the milk also enters into the question of suitability of milk for starter making, since it is the products of citric acid fermentation that provide the volatile acids, and the neutral flavor substances acetoin and diacetyl. The results of a great multitude of citric acid determinations of milk by several investigators show that, while the per cent citric acid of milk may vary considerably with individuality of cow, breed, period of lactation, feed, and season of year, the normal range of fluctuations falls approximately within the limits of .15 and .25%, averaging about .18 to .2%. Greater variations do occur occasionally, however. Thus Sherwood and Hammer[33] reported a range of .07 to .33%. The tendency is for summer milk to be somewhat higher in citric acid content than winter milk, but these seasonal

fluctuations are not great. The spontaneous souring of milk, however, will cause its citric acid content to disappear in two to four days, as demonstrated by Templeton.[30]

Since the volatile acid and the diacetyl that constitute the desired aroma and flavor products, are the result of bacterial fermentation of citric acid, the citric acid content of the starter milk is of primary importance. The possibility of its deficiency in milk that fails to yield a satisfactory starter in the presence of citric acid-fermenting streptococci, suggests the advantage of adding to the milk a small amount of citric acid, or its equivalent in the form of sodium citrate. The addition of .15% citric acid has been found adequate for this purpose and has in many cases greatly improved the intensity of the desired aroma and flavor of the starter. The practice of reinforcing the milk intended for starter appears of special merit at times of starter difficulties, rather than for routine work in starter making. Such reinforcement is advisable also, where it is intended to use the starter for the preparation of concentrates of butter aroma by distillation.

Pasteurization of Milk for Starter Culture.—Since a good starter culture is a pure culture of selected organisms, it is indispensable that the milk to be inoculated be as free from miscellaneous germ life as possible. Thorough pasteurization at a temperature sufficiently high to destroy the maximum number of bacteria is essential. Experience has amply demonstrated that heating to 180° F. and holding the milk at that temperature for one hour is adequate.

Neither pasteurization by the holding method (145° F. for 30 minutes), nor flash pasteurization at temperatures of 180° F. or above, without holding, are satisfactory for the propagation of starter, because of the relatively high bacterial count left in the milk, usually involving species of bacteria that interfere with the desired activity of the selected starter organisms.

Higher temperatures or longer periods of holding than 180° F. for one hour, respectively, short of temperature-time exposures sufficient to insure complete sterilization, are of no particular added benefit. In fact, they may prove objectionable on account of their tendency to produce a cooked flavor in the starter. Theoretically, heat treatment that destroys all organisms in the milk is the ideal, and sterilization of the milk before

inoculation is in fact the routine practice in many starter culture laboratories, especially abroad. In this country thorough pasteurization is given preference over complete sterilization.

The milk for the starter culture may be pasteurized in bulk and then poured into sterilized containers (preferably quart glass jars with glass covers), or the containers may be filled with the unpasteurized milk and pasteurized in the container. The latter procedure is preferable as it eliminates the danger of recontamination of the pasteurized milk when handling it after heating, such as when dipping from a vat after pasteurization.

Pasteurization of the milk in the jars is conveniently done by the use of a metal box of suitable size, with a false bottom, steam and water inlets, overflow pipe, drain, and cover. The jars filled about ⅔ full with milk are set in this box. The level of the water in the box should be high enough to submerge the jars as far up as the milk reaches. The jar covers are put on loosely, the box is covered and the water is heated to 180° F. and held at that temperature for one hour, after which the hot water is gradually replaced by cold water until the temperature of the milk has dropped down to 72-70° F., when the jars are ready for inoculation.

Temperature of Incubation. — For satisfactory incubation, dependable temperature control is essential. Wide fluctuations in temperature during the incubation period jeopardize the quality of the starter culture. For best results the culture should be incubated at a constant temperature until the desired point of coagulation has been reached. At this point a good culture has a firm "set" of curd, which breaks away from the side of the jar like a jell, and can be broken down into a homogeneous, smooth, viscous fluid of the consistency of cream, by shaking.

The most satisfactory solution for maintaining a uniform incubating temperature is that of providing a small room, exclusively devoted to starter work, with definite temperature control for the whole room, and with provisions for the preparation and incubation of the small culture, and for the ripening of the large starter. Where facilities do not permit such an arrangement, a suitable incubator, just large enough to accommodate the culture jars for the small culture, will serve the purpose very well. The incubator should be efficiently insulated

and equipped with thermostatic control. Numerous satisfactory incubators, constructed for this purpose, are now available at moderate cost.

Under practical operating conditions, and with a 1% rate of inoculation, an incubation temperature within the range of 68 to 72° F. has been found most suitable. Experimental results of Toens and Hammer[34] show that good starters may be secured over as wide a range of temperatures as 65 to 90° F., but these investigators also found a range of 68 to 72° F. most satisfactory. During the hot weather season, when there is a tendency in the direction of excessive acid development, an incubation temperature slightly below 70° F. (68° F.) is usually preferable. In winter an incubating temperature of 72° F., or slightly higher, facilitates the acid development necessary for best results.

In the case of the large starter, ripened in the general manufacturing room, the ripening period is often subject to wide variations in temperature, particularly in the case of small batches of starter, by reason of the generally inadequate insulation of the starter equipment and the inevitable influence of the atmospheric temperature on the temperature of the factory room. Under these conditions it becomes necessary to lower or raise the inoculating temperature in accordance with previous observations of fluctuations of room temperature and experience with flavor development. It is especially during sub-zero weather, that the temperature of the starter may drop overnight to a point seriously interfering with acid development. In such cases the inoculating temperature should be sufficiently high to prevent the temperature of the starter from dropping much below 68° F. by morning.

Period of Incubation and Rate of Inoculation.—The incubating period will naturally vary with the temperature of incubation and the rate of inoculation. For both, the small culture and the large starter, with an incubating temperature of 70 to 72° F., and an inoculation rate of 1%, the period of incubation of a satisfactory culture is usually about 15 to 16 hours. In the case of the large starter, efforts to shorten the period of incubation to 8 hours, or less, in order to limit it to the working hours of the factory routine, necessitate considerably higher incubating temperatures, such as 80 to 90° F. While good starters can be

developed by this method, satisfactory control of the fermentation is somewhat more difficult, particularly because of the danger of spore-producing organisms and other forms of germ life that survived the temperature of pasteurization, to grow and predominate before the acid producers gain the ascendancy.

Acidity at End of Period of Incubation.—While aroma and flavor, rather than acidity, are the ultimate goal of a good starter, acidity is an important factor in the production and control of the character of the starter. Experience in starter work has emphasized that efforts to produce low-acid starter usually yield uncertain and often disappointing results. It appears that an acidity range of about .80 to .90% acid, or a pH of about 4.1 to 4.3, is most favorable to the development of maximum aroma and flavor.

Air Requirements.—The development of aroma and flavor in the culture requires the presence of air or oxygen. It has long been known by the practical buttermaker that frequent agitation of the cream during ripening enhances the flavor character of both cream and butter. Attention to air supply is of special significance in connection with the small starter culture, as this is incubated and carried in closed containers.

This was early recognized by Cordes[35] who found that the mother culture in one-quart jars showed better flavor when the jars were filled about two-thirds full, than when they were filled full. Similar observations were made by Toens and Hammer[34] and they further reported that when carrying a culture under uniform conditions of air supply through a series of transfers, better results were obtained in the presence of a moderate air supply than with either an abundant or a restricted supply of air.

Later work by Virtanen,[36] and by Van Beynum,[23] showed that under anaerobic condition no diacetyl was produced, while the presence of an abundant supply of air, or oxygen, during incubation, increased the production of acetoin and enhanced the formation of diacetyl. Virtanen further reports that when incubating the culture in thin layers, of a depth of .5 to 1.0 inch, there is very vigorous production of acetoin, even without the addition of citric acid.

More recently Brewer, et al[37] found that the diacetyl in butter cultures and in pure cultures of citric acid-fermenting

organisms can be greatly increased (as much as several 100%), by incubation under air pressure (30 lbs. per square inch) in the presence of agitation. This treatment also greatly increased the acetoin in some cases, but not in others. Such cultures have the alternative advantages of either producing butter with an unusually high flavor and aroma, or of employing a smaller amount of culture and still attain the same flavor and aroma that result from normal amounts of culture. The added equipment and facilities required for incubation under air pressure, however, are as yet beyond the practical reach of the average creamery.

Handling of Culture after Incubation Period.—At the end of the incubation period, the culture is ready for use for the inoculation of the milk for the big starter. If not used then, the culture should be cooled to 40° F., or below, and held at that temperature until ready to use, in order to avoid overripening and excessive acid production. This is usually conveniently done by setting the culture jars in ice water or other cold water. Providing a permanent place for this cold water bath (a pail or a shallow pan) in the butter cooler, facilitates maintenance of the low temperature.

Holding the cultures in the cooler does no harm to them, even when held for several days. On the contrary, there is a tendency for acetoin + diacetyl and for the flavor and aroma to increase somewhat during the holding period. When it is necessary to make culture for buttermaking every day, the flavor is usually benefitted by the use of small cultures several days old. This applies both, for inoculation of fresh jars of milk for mother culture, and for inoculating the milk for the large starter.

The large starter in the vat is also benefitted by aging, especially in the absence of cream ripening, i.e., where the starter is added to the cream just before churning. The freshly coagulated starter often has as yet but little flavor and aroma, and is much improved by aging. The availability of two starter vats is of material assistance, permitting the ripe starter to be held in the vat until the following day, while the other vat is available for a new batch of starter milk. The starter should be cooled to approximately 40° F. at the end of the ripening period and held at that temperature until used. Where the

starter equipment is limited to one vat only, the cooled starter may be drawn off into clean cream cans and placed in the butter cooler.

Prolonged holding, however, may result at times, in the development of oxidized or metallic flavor. This danger is usually greatest in case the starter is in a whipped-up condition due to excessive incorporation of air. The appearance of the metallic character is further encouraged by exposure to copper surfaces. While metallic flavor is capable of developing in the complete absence of metallic salts, the salts of copper, especially, are very damaging. It is important, therefore, to keep copper surfaces in starter equipment well tinned.

Sanitation.—Scrupulous cleanliness and sanitation of equipment and handling are indispensable in every phase of starter culture work. The laws of sanitation are simple. They resolve themselves largely into the intelligent application of ordinary common sense. The philosophy of starter cultures rests on the propagation of selected species of bacteria and of them only. Failure to observe ordinary sanitary precautions unavoidably invites damaging contamination of the culture with organisms—bacteria, yeasts and molds—that may themselves produce objectionable flavors and odors, or that may interfere with the proper functioning of the desirable lactic acid bacteria and the citric acid-fermenting streptococci. Cultures and starters so contaminated are incapable of improving the flavor of butter, and in most cases they are a detriment to quality.

In addition to pasteurization of dependable efficiency, all equipment and instruments that come in contact with milk after pasteurization must be clean and sterile. This refers to culture jars and their covers, thermometers, spoons, cups, pipettes, dippers, pails, incubator, sanitary pipe lines, fittings, pumps, cans, and vats. It means clean hands of the operator and pure air in the room where culture and starter are handled. It means precautions in handling, that preclude direct contact of the milk, culture or starter with human fingers or tongue. It means metallic surfaces in equipment that are free from milk stone deposits and from rust and other products of corrosion, it means absence of surfaces of bare copper and bare iron.

Commercial Starter Cultures.—These are starter cultures that are prepared by commercial laboratories, usually from

carefully selected species of bacteria. The majority of the good commercial cultures placed on the market today appear to be mixed cultures of lactic acid bacteria and citric acid-fermenting streptococci. They are available either in liquid form or in the form of a dry powder.

The carrier of the liquid culture is usually milk, or nutrient beef broth, or whey bouillon. In the liquid cultures the organisms are present in active condition. They, therefore, respond readily when propagated, and are capable of yielding a culture suitable for use in starter making in a short time. Their chief disadvantage lies in their perishableness. They do not keep well, because in the liquid medium the organisms continue to grow until their own products destroy their virulence. They do not lend themselves satisfactorily for prolonged journeys to distant destinations, especially in the case of shipments during warm weather, or to warmer climes. They must be used while relatively fresh. The addition to such cultures of a small amount of chalk (calcium carbonate) has been found helpful in prolonging their life.

The dry, or powdered cultures are made from good starter culture to which has been added a sufficient amount of inert, dry filler, to absorb most of the free moisture, such as powdered milk sugar, skimmilk powder, chalk, or starch. The mixture is then dried at low temperature, usually under reduced pressure.

In the dry cultures the organisms are dormant. In this condition they retain their virulence for a considerable period of time and even under adverse conditions of atmospheric temperatures. Such cultures keep well. They are commercially more practical, therefore, than liquid cultures, and are adapted for transportation to distant destinations. Their keeping quality is by no means unlimited, however. They should not be held over from one season to another, but should be used preferably within a few weeks after preparation. Because of the state of inactivity of their organisms, the powdered cultures are somewhat slower in regaining their full activity. They usually require several propagations before they can be depended upon to yield cultures satisfactory for use in starter making.

DIRECTIONS FOR MAKING MOTHER STARTER

What is Mother Starter?—The daily handling of large

batches of starter in the creamery under average commercial conditions is accompanied by more or less contamination with micro-organisms of questionable character. Temperature control in the starter vats, cans or tanks is also frequently inadequate to insure uniform results. There is, therefore, always some danger of the starter becoming unsuitable for further propagation. For these reasons it has been found advisable to propagate starter culture on a small enough scale to permit of more complete control of all conditions essential to freedom from contamination and to keep the desirable starter organisms in active condition. This has led to the practice of carrying a small culture of starter from day to day, in addition to the big batch of starter which is added to the cream. The small culture is called starter culture, mother starter, or startoline. Its propagation thus assures the availability of enough good, pure, active culture each day, for inoculation of the milk which becomes the big starter that must be added to the cream for ripening.

The carrying of mother starter is necessary also whenever a new commercial culture is used, since generally, several propagations are required before the culture can be brought back to a sufficiently normal activity to produce a satisfactory starter.

Mother culture, mother starter, or startoline is, therefore, a small culture of the desired starter organisms, propagated from day to day, or as frequently as necessary and in a manner to serve as suitable inoculating material of the starter milk in the vat.

Equipment for Preparation of Mother Starter.—The successful propagation of a good mother starter requires systematic and careful work, and close attention to the details of cleanliness and temperature control. This can be accomplished only when definite equipment, simple but adequate, is provided. Without such equipment the operator is at a disadvantage, the work is prone to be of makeshift character, and the results are often unsatisfactory. Proper equipment not only provides the necessary facilities for accuracy, but it is also indispensable from the standpoint of dignifying the work in the mind of the operator. The following equipment is recommended:

1. One metal box equipped with door, or removable cover, steam inlet, drain, and vent, for sterilizing all small utensils used in the propagation and handling of the mother starter, such as culture jars, dippers, spoons, pipettes, etc. This box should be

of suitable size. A box 13 inches long, 8½ inches wide and 8½ inches deep has been found very serviceable.

2. One insulated culture box, or incubator, with drain hole and insulated cover, or door, and connections and accessories for dependable temperature control.

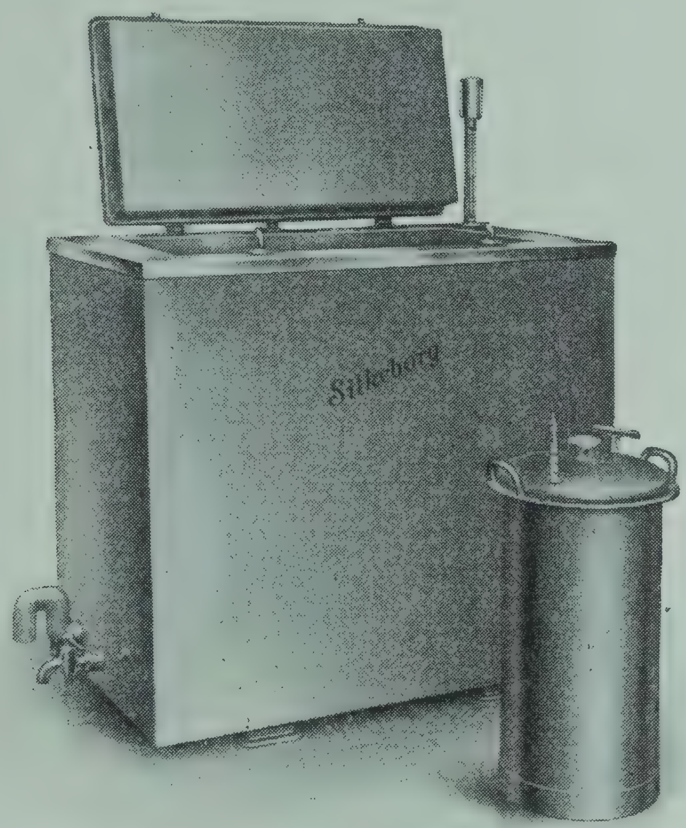


Fig. 55. Culture apparatus, insulated and with electric control
Courtesy of Silkeborg Maskinfabrik

3. One-quart fruit jars with glass lids, or glass containers of any other size. The use of larger jars, such as two-quart bottles may be preferred to quart jars.
4. One accurate dairy thermometer.
5. One long-handled dipper for filling the jars.
6. One dessert spoon.
7. One tin pail or other receptacle for hot water in which to rinse thermometer, dipper, cups and spoon.
8. One table on which to set jars when transfers are being made.
9. One box containing ice water or crushed ice in which to cool and hold the jars of startoline until needed.

Preparation of Startoline.—When beginning with a new commercial culture the following procedure has been found suitable:

First Propagation.—Thoroughly wash and rinse all jars, spoon, dipper, and thermometer, and sterilize them by placing

them in steam-heated sterilizer for not less than one hour. Fill a sterile jar two-thirds full with milk or skim milk of good quality. Pasteurize by heating to and holding at 180°F. not less than one hour. Time may be saved by heating the milk before filling into the jar, or by taking the pasteurized milk from the big starter vat. It is obvious, however, that the danger of bacterial contamination is greatly minimized by pasteurizing direct in the jars. Cool to such a temperature as given in the directions furnished by the manufacturer of the culture. If no directions are available, cool to about 80° F. and pour the commercial culture from bottle into the milk, mix thoroughly, seal the jar with lid, set into culture box, and hold at above temperature until a soft coagulum has formed, that is just sufficiently firm to smoothly break away from the side when jar is tilted. This usually requires from 18 to 24 hours for the first propagation.

Second Propagation.—Prepare utensils as directed under "First Propagation." Set six sterile culture jars with lids loosely on upon the table. With sterile dipper from sterilizer, fill each of the six jars two-thirds full of pasteurized milk from starter vat, and replace lids. Or, pasteurize the milk directly in the jars as in the first propagation. Cool to about 75°F.

Shake the jar containing the first propagation until the coagulum is reduced to a uniform liquid. With sterile spoon from sterilizer transfer one spoonful of the startoline of the first propagation into each of the first two jars, two spoonfuls into each of the next two jars and three spoonfuls into each of the last two jars. Seal the jars and mark them 1, 2, and 3, respectively, according to number of spoonfuls startoline used. Shake each jar thoroughly and set at about 75°F. until the proper coagulum has formed. Then they should be placed in crushed ice or ice water until needed.

Third Propagation.—Prepare six new jars of starter milk as directed under "Second Propagation," cool to 70°F. and "line them up" on table with lids on loosely.

Now thoroughly shake the six jars of the second propagation, then loosen seals preparatory to inspection and transfers. Test each jar for flavor and aroma by pouring a small amount into a cup and tasting and smelling, replacing lids on each jar as fast as sampled.

Select the jar showing the cleanest flavor and most pro-

nounced aroma, and use this jar for inoculation of the jars of the third propagation. Place the newly inoculated jars into culture box and hold them at 70°F. Pour the remaining startoline of the second propagation into the big starter milk. When the contents of the third propagation are coagulated to the point where the coagulum breaks away smoothly from the tilted jar, place the jars in ice water or crushed ice until needed.

Succeeding Propagations.—Follow directions under "Third Propagation" for succeeding propagations.

As previously stated, a temperature range of from 68° to 72°F. has been found most conducive to a uniformly good starter. It is, therefore, recommended that the startoline be cultured at temperatures within this range.

In hot weather when the tendency is for the temperature during incubation to rise, set the milk at 68°F. In cold weather when the trend is downward, set the milk at 72°F. The more complete the temperature control and the more uniform the temperature during incubation, the more dependable will be the results.

It is desirable to establish a routine of startoline work that will cause the culture to be ready at about the same time each day. When culturing at a uniform temperature each day, the time required for coagulation is largely controlled by the amount of inoculating material used. At 70°F, the use of from one to three teaspoonfuls of startoline of the previous day's propagation will usually produce the desired coagulum in from 14 to 16 hours.

It has been found desirable in commercial operation to "set" the new jars the last thing in the afternoon, at about 5 P. M. In this manner the fermentation is usually sufficiently advanced and a nice smooth coagulum has formed by about 7 to 9 o'clock the following morning.

Some operators prefer to "set" the startoline the first thing in the morning and remove the jars from the culture box in the afternoon. This requires a somewhat more rapid coagulation, and consequently the use of a larger amount of startoline for inoculation.

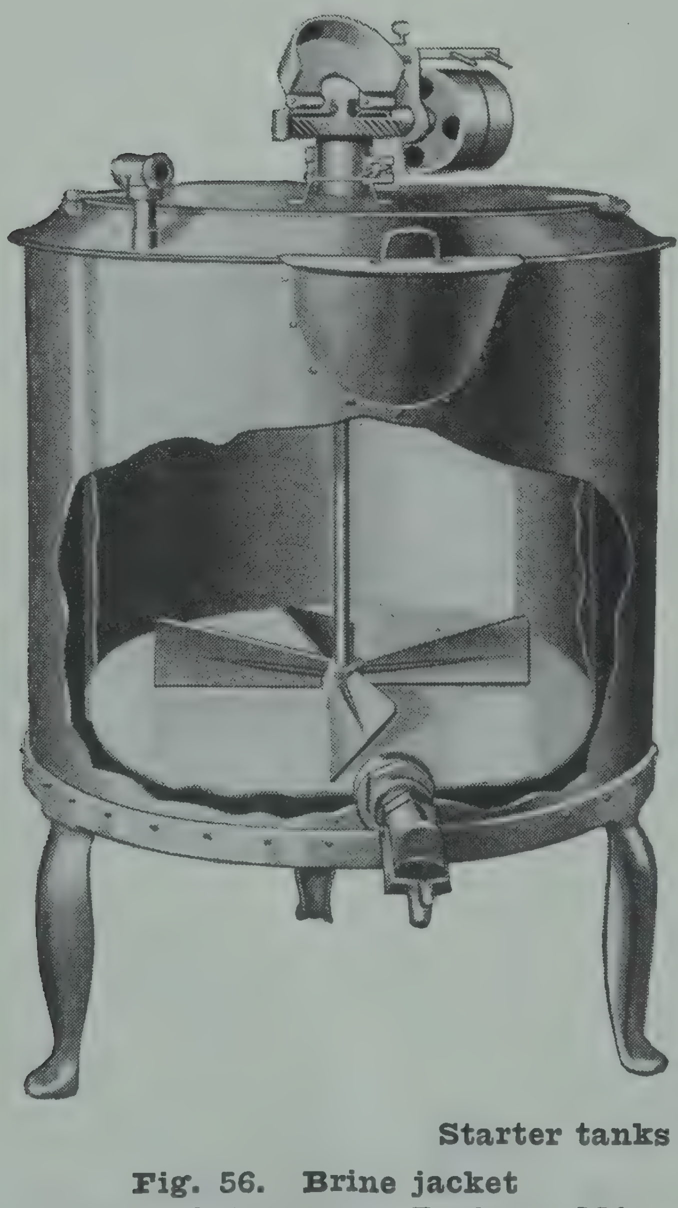
Our present conception of an ideal starter culture is a culture moderately sour with a pronounced "nutty" flavor and high aroma, and a rich, smooth body. High temperatures raise the

acidity at the expense of flavor and aroma. Culturing at between 68° and 72°F. according to season and atmospheric temperature conditions appears to produce the most satisfactory combination of acid, flavor, aroma, and body. An acidity of about .8% to .9% is usually associated with high flavor and aroma.

DIRECTIONS FOR MAKING "BIG" STARTER

Good quality milk, sterile utensils and equipment, and proper temperature control are all important. The absence of any one of these essentials ultimately means poor starter.

Quality of Milk.—Fresh, sweet whole milk, purchased direct from dairy farms on which a high standard of sanitary production prevails, generally yields the most satisfactory starter, both as to quality and economy of manufacture. Skim milk, if of good quality, is also suitable for this purpose, but when it must be purchased it often proves somewhat more expensive. Con-



Starter tanks with agitators

Fig. 56. Brine jacket
Courtesy of Creamery Package Mfg. Company

Fig. 57. Direct expansion coil
Courtesy of Pfaudler Co.

densed milk and milk powder, though serviceable in the absence of whole milk and skim milk, are less satisfactory media for starter making. Under favorable conditions they may yield reasonably satisfactory results, but quite often their use conveys to butter a distinct off-flavor. Skim milk powder deteriorates with age, it should, therefore, be reasonably fresh when used.

Equipment for Making "Big" Starter.—Equipment for this purpose should provide adequate facilities for temperature control. Where only a small amount of starter is needed, the milk may be heated in ten gallon milk cans by setting the cans in a vat containing boiling hot water. For large quantities of starter milk special equipment is desirable. The circular starter can, with insulated water jacket and revolving agitator, has been found very convenient for this purpose and is in general use in many creameries. In creameries with a large make standard cream ripening vats with coil agitator are generally used for starter making.

The surfaces with which the milk and starter come in contact should be of such character as to guard against metallic action in the milk, as explained in Chapter IV. The manner of agitation should be of a nature that avoids excessive air incorporation and injury to the body of the starter. Efficient insulation of whatever form of equipment used is important. One of the greatest weaknesses of much of the available starter equipment is its inability to maintain a uniform temperature.

Making the Big Starter.—Heat the starter milk to 180° F. and hold for at least one hour. Then cool to 68° to 72°F. according to season. Keep cover down while cooling. The milk is now ready for the mother culture. It is desirable to use from about two to four quarts of mother culture per 100 gallons of starter milk. Mix thoroughly, with cover down, by agitating for about 10 minutes.

The "setting" of the starter milk is generally best done toward the end of the day's work, and under proper conditions the starter has usually progressed sufficiently to show a satisfactory coagulum by the beginning of factory operations the following morning. If examination shows a nice smooth coagulum the starter should be cooled at once to 40°F. or below. An incubation period of 15 to 16 hours is usually adequate. In case no coagulum has formed by morning, hold longer and, if neces-

sary to hasten coagulation, raise the temperature slightly. This emergency is exceptional when a good culture is used.

It is advantageous to have available two starter tanks, so that the cooled starter may be left in the tank until needed, while the second tank may serve to receive the new milk for preparation for the next day's starter.

The Proper Degree of Ripeness.—As explained earlier in this chapter, the production and presence of acid in a starter is necessary in order to make possible the proper functioning of the flavor bacteria. In the presence of a suitable quality of milk, inoculation with an active culture of acid and flavor organisms, and reasonable temperature control, the proper degree of ripeness usually shows a titratable acidity of about .80 to .90%. This acidity is generally attained by the end of a ripening period of 14 to 16 hours and is accompanied by a firm "set" of curd that breaks down to a smooth creamy consistency upon agitation.

REFERENCES

1. STORCH, V., Danish Expt. Sta. 18th Ann. Rept, Copenhagen, (1890).
2. ORLA-JENSEN, S.: Die Bakteriologie der Milchwirtschaft, (1913).
3. HANSEN, S., Milch Ztg. *26*, 590, (1897).
4. WEIGMANN, H., Milch Ztg. *19*, 593, (1890).
5. CONN, H. W., Conn. Agr. Expt. Sta. Ann. Repts., (1889-1900), also Buls. 4, 12, 16 and 21.
6. CONN, H. W., Conn. Agr. Expt. Sta. Bul. 21, (1900).
7. WEIGMANN, H., Milch Ztg. *23*, 321, (1894).
8. McDONNELL, M. E., Univ. Kiel Diss., (1899).
9. WEIGMANN, H., Indust. Laitière *33*, 18-19, (1908).
10. STORCH, V., 102 de Beretning fra Forsogslaboratoriet, (1919).
11. HAMMER, B. W., and BAILEY, D. E., Ia. Agr. Expt. Sta. Res. Bul. 55, (1919).
12. BOEKHOUT, F. W. J. and OTT DE VRIES, J. J., Zentbl. f. Bakt. II, *49*, 373, (1919).
13. ORLA-JENSEN, S., Lettres de Danemark, Sect. de. Sci. *8*, 5, 2, 81-196 (1919).
14. HAMMER, B. W., Ia. Agr. Expt. Sta. Res. Bul. 63, (1920).
15. HAMMER, B. W., Ia. Agr. Expt. Sta. Res. Bul. 65, (1920).
16. HAMMER, B. W., Ia. Agr. Expt. Sta. Res. Bul. 67, (1921).
17. HAMMER, B. W., J. D. Sc. IV, *4*, (1921).
18. SCHMALFUSS, H., Zeitschr. Angew. Chem. *41*, 847, (1928).
19. SCHMALFUSS, H., and BARTHMEYER, H., Biochem. Zeitschr. *216*, 330, (1929).
20. VAN NIEL, C. B., KLUYVER, A. J., and DERX, H. G., Biochem. Zeitschr. *210*, 234, (1929).
21. MICHAELIAN, M. B., FARMER, R. S., and HAMMER, B. W., Ia. Agr. Expt. Sta. Res. Bul. 155, (1933).
22. MICHAELIAN, M. B., and HAMMER, B. W., Ia. Agr. Expt. Sta. Res. Bul. 179, (1935).
23. VAN BEYNUM, J., XI. World Dairy Cong. II, *2*, 70, (1937).

24. HAMMER, B. W., STAHLY, G. L., WERKMAN, C. H., and MICHAELIAN, M. B., Ia. Agr. Expt. Sta. Res. Bul. 191, (1935).
25. MATUSZEWSKI, T., PIJANOWSKI, E., and SUPINSKA, J., XI. World Dairy Cong. II, *2*, 80, (1937).
26. RITTER, W., and NUSSBAUMER, Th., Schweiz. Milch Ztg. 77-79, (1936).
27. FABRICIUS, N. E. and HAMMER, B. W., Ia. Agr. Expt. Sta. Res. Bul. 221, (1937).
28. TEMPLETON, H. L., and SOMMER, H. H., J. D. Sc. XII, *1*, 21, (1929).
29. TEMPLETON, H. L., and SOMMER, H. H., J. D. Sc. XVIII, *2*, 97, (1935).
30. TEMPLETON, H. L., Wis. Agr. Expt. Sta. Res. Bul. 133, (1937).
31. VAS, K., and CSISZAR, J., XI. World Dairy Cong. II, *2*, 114, (1937).
32. CORDES, W. A., Butter and Cheese Symposium, Consol. Reporting Co., N. Y. p. 81, (1938).
33. SHERWOOD, F. F., and HAMMER, B. W., Ia. Agr. Expt. Sta. Bul. 90, (1916).
34. TOENS, P., and HAMMER, B. W., Ia. Agr. Expt. Sta. Res. Bul. 85, (1925).
35. CORDES, W. A., Blue Valley Res. Labs. (not published), (1928).
36. VIRTANEN, A. I., XI. World Dairy Cong. II, *2*; 121, (1937).
37. BREWER, C. R., WERKMAN, C. H., MICHAELIAN, M. B., and HAMMER, B. W., Ia. Agr. Expt. Sta. Res. Bul. 233, (1938).

CHAPTER XIV

CREAM RIPENING

Definition.—As a part of the process of butter manufacture, as practiced in the present-day creamery, cream ripening refers to the treatment which the cream receives, if any, and the changes it undergoes, in flavor, aroma and texture, between pasteurizer and churn.

Purpose.—The fundamental objects of cream ripening are to produce butter with a pleasing, pronounced flavor and aroma, and to produce this flavor and aroma uniformly from day to day. Ripening also influences somewhat the exhaustiveness of churning and it affects the keeping quality of the butter variously, according to quality of original cream, churning acidity, and whether made into salted or unsalted butter.

EFFECT OF CREAM RIPENING ON BUTTER

Effect on Flavor and Aroma.—The mildly acid and pronounced "nutty" flavor that is characteristic of the pleasing flavor of good butter is usually accompanied by a high, attractive aroma. As shown in Chapter XIII on "Starters and Starter Making," the typical butter flavor is due to the presence of diacetyl in combination with lactic acid, volatile acid, carbon dioxide, acetoin and intermediary products such as acetaldehyde, and probably other aromatic products as yet not definitely determined. These substances are the products of fermentation, brought about by the associative action of lactic acid-producing bacteria and citric acid-fermenting bacteria.

These bacteria are propagated and their flavor and aroma substances produced in the starter. During cream ripening the starter that is added to the cream, therefore, functions in two ways. It seeds the cream with species of bacteria that are capable of producing the desired aroma and flavor substances in the cream, and it adds to the cream the aroma and flavor substances produced and already contained in the starter.

Factors which Influence the Diacetyl + Acetoin Content of Butter.—Cream that arrives at the creamery in sour condition

usually contains considerable amounts of diacetyl + acetoin, while cream that arrives sweet may contain small amounts or none at all, as shown by Michaelian & Hammer[1], Virtanen[2], and Krenn[3]. Cream ripened with a normal starter shows a varying ratio of diacetyl to acetoin. Mohr and Wellm[4] emphasize that this ratio, when using the same cultures, varies within a rather wide range (1:12 to 1:26) with the ripening temperature, the acidity at the end of the ripening process, and with the fat content of the cream. In the case of 20% cream, a ripening temperature of 17°C. (62.6°F.) yielded the largest amount of diacetyl. With increasing fat content the amount of diacetyl + acetoin increased. Cream testing 40% fat yielded a higher diacetyl content in the butter than 20% cream, or whole milk. A churning temperature of 14°C. (57.2°F) gave the highest content of diacetyl + acetoin in the fresh butter.

Davies[5] found the diacetyl content of butter to affect its flavor as follows:

Amount of Diacetyl	Flavor
Absence of diacetyl	Flavorless
.2 to .6 p.p.m. diacetyl	Mild flavor
.7 to 1.5 p.p.m. diacetyl	Full flavor

Distribution of Diacetyl + Acetoin by the Churning Process.—Butter contains a relatively small proportion only of the diacetyl + acetoin content of the cream from which it is made. Fresh buttermilk contains larger amounts of diacetyl + acetoin than the corresponding butter and than the original cream at churning time. The serum of butter contains larger amounts of diacetyl + acetoin than the fat of the same butter. The wash water contains appreciable amounts of diacetyl + acetoin.

Michaelian and Hammer[1] found the ratio of diacetyl + acetoin in the cream to the amounts found in the butter to vary from 1:0.032 to 1:0.218, and the ratio in the cream to the amounts found in the buttermilk to vary from 1:1.1 to 1:3.1. Mohr and Wellm[4] reported from 2.4 to 4 times as high a diacetyl content in the fresh buttermilk as in the cream at churning time. Davies[5] places the ratio of diacetyl content of cream to butter at approximately 4:1 to 5:1. Krenn[3] also observed that while skimmilk and sweet cream were always free from diacetyl, the starter, and especially the ripened cream at churning time, were rich in diacetyl, that large amounts of diacetyl

were found in the buttermilk and comparatively little diacety in the butter.

Krenn, and also Mohr and Wellm found considerabl amounts of diacetyl in the wash water of butter, showing that by prolonged and excessive washing of the butter, aroma is sacrificed. Krenn, churning 2 liters of cream found the following amounts of diacetyl in the buttermilk, wash water and butter:

Buttermilk	6.14 mg Diacetyl
First wash water..................	3.16 mg Diacetyl
Second wash water................	0.00 mg Diacetyl
Third wash water.................	0.00 mg Diacetyl
Butter	0.30 mg Diacetyl

Mohr and Wellm[4] showed the following amounts of diacetyl + acetoin in washed and unwashed butter:

	Diacetyl mg/kg	Diacetyl + Acetoin mg/kg
Unwashed Butter	1.69	9.30
Washed Butter	0.86	3.78

These findings support the observations of Hunziker[6], that in commercial manufacture of butter, particularly in the case of unsalted butter, excessive washing gives the finished butter, even when made from properly ripened cream, a disappointing "washed-out" flavor.

That considerable amounts of diacetyl are usually formed during the churning process was observed by several investigators. Davies[5] points out that butter made from ripened cream requires 12 to 24 hours holding before the full flavor develops. He holds that some acetoin in the butter is oxidized to diacetyl during that period, that there is practically no oxygen in solution left in ripened cream, while freshly churned butter is saturated with air, and that metabolism of the residue of starter bacteria then readjusts the diacetyl + acetoin ratio according to the new oxygen conditions. Along similar lines Krenn[3] assumes that during the churning process some diacetyl is formed from the acetoin present, by reason of the abundant incorporation of atmospheric oxygen in cream and butter during the churning and working process.

Davies further holds that the situation is somewhat different in the case of butter made from sour, neutralized, pasteurized cream. He found no trace of diacetyl + acetoin in such

butter and reports absence of aroma and flavor. He attributes this situation to the volatilizing effect of pasteurization, and aeration during cooling, and to the absence of oxidation and autoxidation of the acetoin in the manufactured butter. Obviously the ripening of the neutralized, pasteurized cream eliminates the major causes of absence of diacetyl and aroma in such butter. It is a fact, however, that the sour, neutralized cream is not as favorable a medium for the satisfactory functioning of the starter bacteria, as is pasteurized sweet cream.

Flavor and Aroma Influenced by Factors Other Than Cream Ripening.—The foregoing findings do not preclude the possibility that the character and intensity of flavor and aroma in cream and in butter may be influenced by the feed the cows consume. Aromatic substances contained in the feed may pass into the milk direct. Or they may be physiologically separated from the feed and reach the udder as complex but slightly aromatic products from which volatile and aromatic products are formed during the cream ripening process.

Likewise the breed of cows and the period of lactation may exert a greater or lesser influence on the flavor and aroma found in butter. Some breeds (the Channel Island breeds) produce milk with a higher volatile acid content than others. During the early months of the period of lactation the volatile acidity of the milk is highest. It declines as the milking period advances and is lowest at the end. Thus butter from fresh cows shows more of the pleasant flavor and aroma characteristic of fine butter, than butter made from the milk of stripper cows.

The very fact that such local and seasonal factors as feed, breed and period of lactation do exert an influence on the character and intensity of flavor and aroma of butter, emphasizes the importance and value of subjecting the cream to a properly controlled ripening process, that will insure the desired flavor and aroma regularly in the butter of all churnings, regardless of locality and season of the year.

Effect of Cream Ripening on Keeping Quality of Butter.—Quality of butter is of value only if it is present at the time the butter reaches the trade and the consumer and until it is actually consumed. If quality means anything, it must mean keeping quality. The development of flavor and aroma in butter by cream ripening, or by any other process of manufacture, can be

of value only, provided that it does not impair or destroy the keeping quality of the resulting butter.

The ripening of cream affects the keeping quality of butter in two fundamental ways, namely, by its control of age deterioration due to bacterial causes, and by its influence on age deterioration due to chemical causes.

Bacteriological Effect of Cream Ripening on Keeping Quality.—The ripening of cream improves the keeping quality of butter in as far as keeping quality is dependent on freedom from age deterioration due to biological causes. Cream ripening assists in controlling bacterial deterioration in butter. In butter made from ripened cream there is a great preponderance of lactic acid bacteria and a relatively high acidity and probably an abundance of lactate salts. These agencies are antagonistic to the great majority of flavor-damaging organisms that may be present in the butter, thus retarding their action, preserving the fresh or desired flavor, and prolonging the keeping quality of the butter.

Butter made from sweet cream or cream with a low churning acidity lacks these preservative agencies. In the presence of flavor-damaging organisms, it rapidly yields to bacterial flavor deterioration. Such butter has poor keeping quality, often developing such damaging flavor defects, as cheesy flavor, rancidity, and surface taint, (putrid flavor), etc. These difficulties have been overcome in some instances by allowing the raw, sweet cream to sour naturally (to approximately .45% acid) followed by neutralization, pasteurization, and holding at low temperature overnight, and in others by the addition to the butter of a small amount of lactic acid (1 oz. per 100 lbs. of butter). In the manufacture of butter from sweet, unripened cream, efficient pasteurization and scrupulous, painstaking sanitation and cleanliness of equipment and operation between pasteurizer and finished package of butter are doubly essential, as shown by Hunziker and Cordes[7] and by Hunziker[8,9].

These observations, irrefutably established by commercial experience, are further supported by the work of St. von Nyiredy[10], who reported that, in the butter made from the ripened cream, the B. coli, proteolytic, and Bact. flourescens types of organisms showed practically no growth, and decreased rapidly, while their count increased markedly in the sweet cream

butter. The ripened cream butter had a pH of 4.6 to 4.8, the sweet cream butter, of 6.4 to 6.8. St. von Nyiredy concluded, on the basis of these results, that the absence of growth of these groups of bacteria in the ripened cream butter is due to the high acid reaction (low pH) of the butter made from ripened cream. He further found that the molds and the apparently indifferent organisms growing on casein agar, proved less sensitive to acid and, therefore, thrive equally well in butter made from sweet cream as from ripened cream.

The menace of early flavor deterioration due to bacterial causes, of butter made from unripened sweet cream is naturally greatest in light-salt and unsalted butter. The higher the salt content of butter the less is the danger from flavor defects caused by bacteria.

Chemical Effect of Cream Ripening in Keeping Quality.—Cream ripening does not improve the chemical stability of butter. On the contrary, under average commercial conditions of manufacture, the ripening of cream to a full aroma and flavor shortens the life of salted butter. The usual flavor defects that develop with age in butter made from fully ripened cream are oily-metallic, fishy and sometimes tallowy flavor. There is a tendency also to intensify the well-known cold storage flavor. This is especially true of salted butter made from cream that arrives at the factory in sour, fermented condition, is neutralized, pasteurized and re-ripened to a high acidity. It applies also, though to a somewhat lesser extent, to salted butter made from ripened sweet cream. It does not apply to unsalted butter.

Salted butter made from sweet, unripened cream, or from sour cream neutralized and pasteurized, keeps better from the standpoint of absence of flavor deterioration due to chemical causes, than salted butter made from the same cream ripened to a full flavor and aroma. These observations are supported by long experience in the commercial manufacture and storage of butter, as well as by the great mass of experimental results of the vast majority of scientific investigations on this subject, as indicated by the following citations:

Storch[11] attributed oily, fishy and bitter flavors to the practice of ripening cream before churning. Patrick, Leighton and Heileman[12] found less deterioration in butter flavor in storage when made from sweet cream than from ripened cream. Dean[13]

obtained butter with better keeping quality from sweet cream than from ripened cream. Gray and McKay[14] found that a fishy flavor resulted in high salted butter made from old cream while high salting did not produce fishiness in butter made from sweet cream. Credicott[15] found that cream churned sweet, made butter of better keeping quality than butter made from ripened cream. Shutt and Sharon[16], as the result of a comparison of sweet cream and ripened cream butter, showed that the keeping quality of sweet cream butter is distinctly superior. Sommerfeld[17] concluded that most butter faults have their origin in the souring of cream.

Rogers[18] found that in all cases where butter became fishy, it had been made from cream high in acid, either developed naturally or added artificially. Rogers and Gray[19] report that there was more deterioration of butter made from high-acid cream than from sweet cream and they conclude that the acid in the cream brings about, or assists in bringing about a slow decomposition of one or more of the labile constituents contained in butter. Thomson[20] concludes that fishiness in butter is largely a chemical change favored by a high degree of acidity and salt and a temperature of storage between 30° and 40°F. Davis[21, 22] found that the samples of butter which scored fishy were made from cream high in acidity and salted over two and one-half per cent. Rogers, Thompson and Keithley[23] demonstrated conclusively the freedom from fishiness in butter made from unripened cream and the tendency of butter made from ripened raw or pasteurized cream to become fishy in storage. Fleischmann[24] states that fishy and oily flavors appear only in sour cream butter.

Dyer[25] attributes the production of off-flavor commonly met with in cold storage butter to a chemical change progressing in one or more of the non-fatty substances occuring in buttermilk. He states that the extent of this chemical change is directly proportional to the quantity of acid present in the cream from which the butter was made. Hunziker[26] pointed out that the pasteurizing and churning of sour cream makes butter of inferior flavor and poor keeping quality. Hunziker[27, 28] further shows that proper neutralization of sour cream and churning at an acidity of not to exceed .30% prevents fishiness in commercial butter with a certainty. Guthrie[29] concluded that high acidity is a necessary condition for the development of

metallic flavor. Rogers[30] reports that of over 5,000,000 pounds of Navy butter made from sweet pasteurized cream without starter, not a pound developed fishiness in six to eight months storage. Cusick[31] attributes fishiness to the solvent action of lactic acid and salt water on the lecithin. McKay and Larson[32] state that butter made from high acid cream invariably becomes fishy in storage. Mortensen[33, 34] reports that butter made from ripened cream deteriorates faster than butter made from sweet cream or sweet cream and starter, but that ripening to a low acidity made butter that was about of the same quality as unripened cream butter. Grimes[35] found greater uniformity of keeping quality in butter made from sweet cream and from sweet cream with starter than from ripened cream. Sommer and Smit[36] demonstrated that acid in cream favors the development of fishiness because acids favor the hydrolysis of the lecithin, intensify oxidative processes in butter, and cause the cream to dissolve iron and copper from the equipment.

White, Trimble and Wilson[37] reported that salted butter made from cream with acidities of .15 to .31% kept well in storage at 0°F. for months. After 12 months butter made from cream with .15 to .25% acid had deteriorated less than that made from cream with .28 to .31% acid. When held at 30 to 50° F. for 4 months, deterioration was greater in butter made from cream of high acidity than that of low acidity. The higher the acidity of the cream at any storage temperature of butter, the greater the deterioration of flavor with age.

Holm, Wright, White and Deysher[38] studied the effect of cream acidity on butter deterioration on the basis of the flavor score, the peroxide value, the time of bleaching at 42°C. (107.6°F.), and by dye reduction tests. The rates of deterioration of sweet cream butters and of butters made from creams of less than .20% acidity developed by pure cultures added to the sweet creams, were practically identical. Butters made from cream of an acidity of .30% or more were inferior in keeping quality to those made from cream of .20% acidity or less. No churnings were made of cream with acidities between .20 and .30%. Their results indicated a direct relationship between rate of oxidation and loss in flavor score, and they concluded that an acid medium was the major factor concerned. Holmes and co-workers used 30% fat cream for their experiments and incorporated approximately 2.5% salt in the butter.

Davies[39] also reported that full-flavored butter (meaning butter made from ripened cream) did not keep well, developing fishy and later tallowy flavor. He attributed the poor keeping quality not so much to the aroma constituents, as to the high serum acidity and its effect on the liberation of organic acids from the butter fat (oleic acid). He further reported superior keeping quality of butter made from low-acid cream and from pasteurized, neutralized cream.

Ritter[40, 41] stated that in his experiments fishy butter occurred only in sour-cream butter and never in butter from cream churned sweet. He further emphasized that the presence of traces of copper or iron greatly hastens the oxidative changes leading to fishiness and similar flavor defects of chemical nature. Mohr and Ahrens[42], on the other hand reported that their experimental salted butter made from 20% cream ripened to 28° S.H. (.63% cream acidity or .787% cream serum acidity) kept as well as butter made from sweet cream. After storage for 8⅔ months at 21 to 42°F. the butter was of good quality. In their trials they used perfectly fresh cream, pasteurized at 95°C. (203°F.) and all operations were conducted under faultlessly asceptic conditions of equipment and handling, eliminating the possibility of bacterial and metallic contamination, and of air during storage. The butter was stored in sealed glass containers. Results of later work convinced Mohr and Ritterhoff[43] that sweet cream butter, if it is not over-neutralized, is not as sensitive regarding maintenance of its quality when it comes out of storage, as ripened cream butter.

Effect of Diacetyl on Keeping Quality of Ripened Cream Butter.—The aroma substance, diacetyl, is present in butter, even when made from fully ripened cream, in exceedingly small amounts. The diacetyl content of such butter usually averages approximately 2.5 p.p.m., and it rarely exceeds 4 p.p.m. While recognized as a potent oxidizing catalyst, capable of intense oxidation of such constituents as butter fat, it is present in such small amounts as to render its effect apparently negligible.

King[44] studied the effect of diacetyl on butter fat oxidation and found that in the presence of air, the butter fat is attacked by the diacetyl, causing tallowiness and bleaching. In the presence of light, oxidation was hastened. However, he worked with much higher concentrations of diacetyl than apply to but-

ter. The lowest concentration of diacetyl used in his experiments was 50 p.p.m, or from 15 to 20 times the amount normally contained in butter. Even a concentration of 50 p.p.m. had practically no effect on, and did not change the aroma of the butter fat held for 97 days at 22-24°C. (71.6-75.2°F.) in the dark, while higher concentrations caused tallowy flavor and bleaching.

That it is the high churning acidity and not the diacetyl content of butter made from ripened cream was further demonstrated by the work of Hunziker and Cordes, involving several thousand churnings made from unripened cream to the butter of which was added diacetyl to the extent of approximately 3 to 4 p.p.m. This butter was held for from 2 to 9 months. In no case was there any indication of bleaching, tallowy flavor, or other flavor deterioration, such as might be attributable to oxidation due to diacetyl.

Other Factors that Influence the Effect of Cream Ripening on the Keeping Quality of Butter.—The above citations of experimental results show, practically without exception, better keeping quality of sweet-cream salted butter, than of salted butter made from cream ripened to an acidity sufficiently high to insure a full aroma and flavor. There are certain conditions of manufacture, however, that permit of controlled ripening without jeopardizing keeping quality and there are still other conditions of manufacture and distribution, under which ripening to a full aroma and flavor is definitely beneficial to keeping quality.

The extent to which cream may be ripened and still have the butter reach the consumer without objectionable flavor deterioration due to chemical changes, is influenced by such factors as: condition and quality of the cream before manufacture, temperature at which butter is held between churn and consumer, whether intended for fresh consumption or for cold storage, whether the cream is used for salted or for unsalted butter, and salt concentration in the salted butter.

Quality of Cream.—The fresher and sweeter the cream, and the more complete its freedom from such metallic salts as the salts of copper and iron, the less is the danger of impairing the keeping quality of butter by chemical changes, when made from ripened cream. Cream that has never been allowed to sour or ferment at any time prior to pasteurization, such as fresh fac-

tory-separated cream, or cream that arrives at the factory in perfectly fresh and sweet condition, will stand ripening to a higher acidity without jeopardizing the chemical keeping quality of butter, than cream that arrives at the factory in sour, fermented condition.

Thus, in the case of cream of inferior quality, the unstable lecithin may have yielded to hydrolysis in the cream itself, inviting early oxidation of the choline and the formation of trimethylamine and fishiness in the resulting butter. Fermentation products and metallic salts may have dissipated the resistance of the fat and exhausted its induction period to a point where active autoxidation commences in the freshly churned butter. Proteolysis may have progressed in the cream, and protein cleavage products may be present by the time of its arrival at the factory, causing the early appearance of objectionable cold storage flavors, such as often develop in butter made from low grade cream.

That cream of inferior quality contains such decomposition products as liberated organic acids (particularly oleic), and nitrogen decomposition products such as soluble nitrogen compounds, amino nitrogen and ammonia substances, in larger quantities than fresh sweet cream, was shown by the work of Ferris[45, 46], and Ferris, Redfield and North[47]. These investigators further found that the above products of decomposition were present to a greater extent in fresh butter and increased more rapidly during storage, in the case of butter made from sour cream than from sweet cream.

Effect of Cream Ripening on Fresh-Consumption Butter. In the United States butter intended for fresh-consumption usually is from about 2 to 6 weeks old before it reaches the consumer. The temperature at which it is held between churn and pantry of consumer varies obviously with many conditions. It is, however, seldom at or below the freezing point (32°F.). The coolers of the creamery and of commission merchants and wholesalers usually carry it at a temperature of approximately 35 to 45°F. In transit, although cars and trucks are iced during the hot weather season, the butter may be exposed to somewhat higher temperatures. The temperature of the ice box or refrigerator in the retail store may vary between about 40 and 60°F.

These very approximate and widely varying temperature conditions suggest that, in general, the temperature to which

fresh-consumption butter is exposed and the period of exposure, are such as to permit of deterioration due to bacterial causes. Bacterial deterioration of fresh-consumption butter is, in fact, a constant menace. It was shown in earlier paragraphs that cream ripening, by reason of the retarding effect of lactic acid bacteria, lactic acid and its salts on the activity of putrefactive and other forms of quality-damaging germ life, assists in delaying flavor deterioration due to bacterial causes. On the other hand, the damaging chemical changes that are promoted by the higher acidity of ripened cream butter, progress more slowly and their jeopardy to the keeping quality of fresh-consumption butter is largely negligible.

For these several reasons it has been found advantageous, in the case of fresh-consumption butter, to neutralize the sour cream to as low an acidity as practicable without giving the butter an objectionable neutralizer flavor, and then ripen it back to the maximum churning acidity (0.25 to 0.30%) that is still low enough to prevent the development of fishy flavor. Such butter averages a more pleasing flavor and is less subject to bacterial deterioration than butter made from cream of similar quality without ripening, and yet it has sufficient resistance to chemical deterioration to keep satisfactorily for fresh-consumption purposes.

Effect of Cream Ripening on Butter Held in Commercial Cold Storage.—In the case of butter intended for commercial cold storage at the usual temperature of -10 to -20°F., the ripening of cream is of doubtful merit, especially when the butter is made from sour, neutralized cream. Under American conditions, storage butter may be held in cold storage from 3 to 12 months, or even longer. From the standpoint of flavor and aroma, the ripening of cream intended for cold storage butter is of little value. As shown in earlier paragraphs, prolonged cold storage of the butter dissipates the diacetyl and its accompanying flavor and aroma. Again, bacteriological deterioration is a negligible factor with butter held in commercial cold storage. The retarding effect of cream ripening on bacterial deterioration of butter, therefore, is unimportant. On the other hand, oxidation processes that are enhanced by the high acidity of butter made from ripened cream, continue their work of flavor deterioration, and the prolonged period of cold storage intensifies the damage done.

For these various reasons the quality of cold storage butter is not benefitted by cream ripening. On the contrary, it suffers greater depreciation than that of butter made from unripened, low-acid cream. Cream churned sweet, and sour cream (.45% acid or less), neutralized to a churning acidity of .15% or lower, gives the resulting butter held in cold storage excellent keeping quality. In the case of high-acid cream the menace of neutralizer flavor usually does not permit of neutralizing to such low acidities. For such cream, a churning acidity of not to exceed .21% has been found preferable. See also Chapter XX under "Keeping Quality of Butter in Commercial Cold Storage."

The Effect of Cream Ripening on Unsalted Butter.—The foregoing discussion of the relation of cream ripening to keeping quality referred to salted butter. In the case of unsalted butter the situation is somewhat different. Bacteriologically, unsalted butter is the most perishable type of butter made. It contains no added preservative, such as salt, that would retard or inhibit bacterial activity. To be sure, efficient pasteurization and a faultless standard of cleanliness and sanitation in manufacture and packing provide maximum freedom from damaging germ life in the butter and assist in retarding bacterial deterioration. However, unless sterilized after manufacture, and packed in hermetically sealed containers, or held at temperatures low enough to permanently inhibit all bacterial growth, unsalted butter is inevitably destined to suffer bacterial flavor deterioration with age.

If made from cream that is churned at a low acidity, such as sweet cream, or sour, neutralized cream, without ripening, early flavor deterioration due to bacterial activity is practically unavoidable, when held at temperatures above the freezing point. If, made from cream ripened to a full aroma and flavor, bacterial deterioration is very noticeably retarded by the great predominance of lactic acid bacteria and the relatively high acidity. These agencies assist in holding in check, the type of organisms which, if present, are prone to cause bacterial flavor defects in unsalted butter.

OPERATION OF CREAM RIPENING IN THE FACTORY

Equipment.—The equipment should be as simple as possible, consistent with sanitary construction, freedom from dam-

aging metal surfaces, efficient temperature control, and economy of operation.

The ripening of cream is usually most conveniently done in vertical or horizontal coil vats, in vats with oscillating coil, or in square or circular tanks with coil, blade or impeller agitator. Tanks with removable coil have also been found suitable. In the creamery that uses vat pasteurization, the vat pasteurizer provides the needed equipment for cream ripening. Plain vats, with or without jacket, and with or without cover, are also used

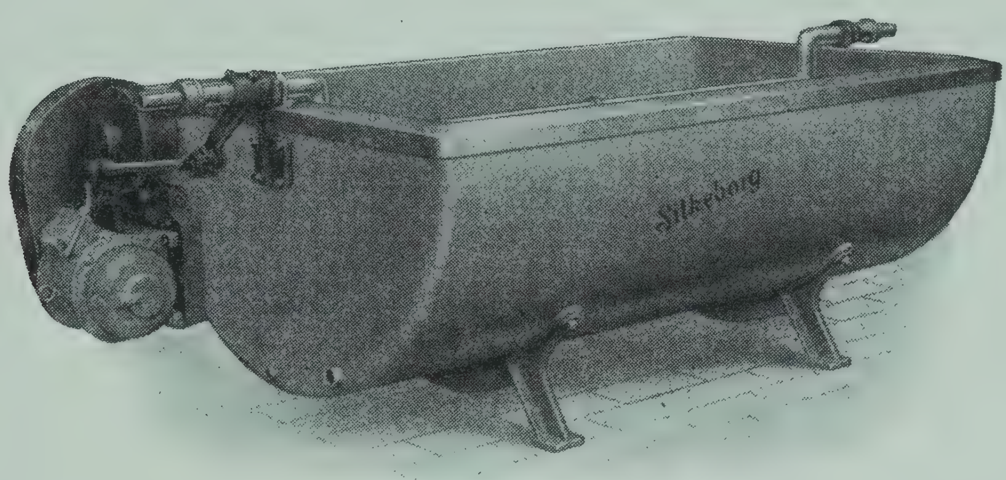


Fig. 58. Cream ripener, jacketed, with swinging coil, stainless steel
Courtesy of Silkeborg Maskinfabrik

for this purpose, especially in some of the European creameries. Their operation usually necessitates the addition of crushed ice for cooling the ripened cream. Insulated coil vats have been found to provide the most practical and labor-saving means of temperature adjustment and control.

Amount of Starter to Use.—The starter is an item of expense in the operating cost of the creamery. For economic reasons, therefore, the amount of starter added to the cream should be limited to that necessary to accomplish the full benefits of cream ripening. The amount of starter actually needed for this purpose depends on such factors as condition and richness of cream, ripening temperature, and ripening period that best fits into the operating routine of the factory.

Fresh, sweet cream requires less starter than sour, neutralized cream. A good quality of sweet cream provides a favorable medium for the activity of the starter organisms. Even when using a small amount of starter in such cream, their ascendency is assured. Old, stale, sour neutralized cream, even after efficient pasteurization, still contains a considerable num-

ber of bacteria, especially species foreign to starter organisms, and usually more or less antagonistic to their activity. Such cream may also contain fermentation products that are a hindrance to the desired starter action. A larger amount of starter is necessary, therefore, to overcome these objectionable agencies. In fact, at best, the flavor and aroma results of starter action in cream of poor quality are not as dependable nor as pronounced as in cream of good quality.

Rich cream requires more starter than cream low in fat. The lower the ripening temperature, and the shorter the ripening period, the larger the amount of starter required to attain the desired, pronounced flavor and aroma that is expected of ripened cream butter.

The amount of starter used by different creameries ranges from about one to ten per cent of the volume of cream to be ripened. The Danish buttermaker who has the advantage of fresh, factory-separated sweet cream, containing about 20 to 25% fat, which he ripens at a relatively high temperature, adds approximately 3% starter to his cream. In this country it has been found helpful to use from 5 to 7% or more starter in sour, neutralized cream of about 90 score quality and containing well over 30% fat. In the northern tier of the dairy belt where the cream averages a lower fat content (usually below 30% fat), and where much of it is of 92 score quality, the addition of 3 to 4% starter is usually sufficient.

Per Cent Acid to Which the Cream Should Be Ripened.—On the European continent where a pronounced flavor and high aroma of butter is preferred, but little attention is paid to the churning acidity of the cream, the ripening process is carried to the point where the cream has a granular, glistening appearance and a pronounced flavor and aroma. Acid tests are not made regularly. Under these conditions the ripened cream usually has a titratable acidity of about 0.55 to 0.65%. This is the general practice in Danish creameries.

In the United States the churning acidity is looked upon as an important factor in determining the keeping quality of the butter, and the churning acidity is controlled by the acid test of the cream. Likewise, in order to hold the churning acidity of cream intended for salted butter down to a safe point, especially with regard to prevention of fishy flavor, the ripening is usually

done at a low temperature (about 48 to 53° F.). In some cases the starter is added to the cream at a higher temperature during the cooling of the pasteurized cream, such as at 70° F., and cooling to churning temperature is continued.

For fresh consumption salted butter, cream of moderate richness (testing about 30% fat) may safely be ripened to about 0.25 to 0.30% acid. In the case of salted butter intended for commercial cold storage it has been found preferable not to ripen the cream, and to churn it at an acidity of about 0.21% acid or lower.

In order to avoid excessive acid development due to cream ripening, some buttermakers follow the practice of adding the starter just before churning. In this case the use of 5 to 7% starter usually raises the acidity of the cream approximately 0.03 to 0.04%. The flavor and aroma of the resulting butter here depend solely on the degree to which they are present in the starter. At best their effect on the butter is slight, and it is pertinently questionable whether this practice is economically justifiable.

In the case of unsalted butter, the cream may be ripened to any acidity without jeopardizing keeping quality. In fact, it is desirable to ripen the cream for this purpose to a full aroma and flavor. Excellent results are obtained by low-temperature ripening, such as at about 50 to 55° F. over night. By this method the cream usually shows a pronounced flavor and aroma the following morning and an acid range of about 0.35 to 0.45% titratable acidity. When ripening at the higher temperatures (60 to 70° F), the aroma character tends to be somewhat more pronounced and the acid somewhat higher (0.5 to 0.65% titratable acidity).

Addition of Citric Acid to Cream for Ripening.—As explained in Chapter XIII on "Starters and Starter Making," the major substances responsible for the characteristic butter aroma and flavor, such as diacetyl, acetoin, volatile acidity and CO_2, are products resulting from the fermentation of citric acid by the starter bacteria. It was further shown that the addition to the starter milk of a small amount (about 0.2%) of citric acid, or its equivalent as sodium citrate, stimulates the production of these products and increases the desired aroma and flavor in the starter.

These facts suggest the possibility of augmenting the desired aroma and flavor in the cream and butter by adding citric acid or sodium citrate to the cream during ripening. According to the findings of Sherwood and Hammer[39] the citric acid content of cream direct from the separator varied from 0.09 to 0.19%, averaging 0.15%; in mixed farm cream it varied from 0.10 to 0.20%, averaging 0.15%.

Data showing the effect of adding citric acid to the cream at the time of ripening, on the resulting butter are limited. Ritter and Stüssi[48] made experimental churnings on a commercial scale, ripening the cream with and without the addition of 0.2% citric acid. The scores of the resulting butter, judged by seven groups of three judges per group, favored the control butter. The butter made from the citric acid cream had a less desirable flavor and aroma than that of the control churnings. This was true of the fresh butter as well as after one month of storage.

In the absence of more favorable experimental data, the addition of citric acid to cream appears to be of doubtful merit, suggesting the wisdom of avoiding this added expense, until more convincing knowledge of its merits is available.

Adding the Flavor Substance Direct to the Butter.—It has been shown in the foregoing paragraphs that cream ripening increases the cost of manufacture, may jeopardize the keeping quality of butter from the standpoint of chemical stability, and that the major portion of the aroma and flavor substances passes into the buttermilk and water used for washing the butter, and is lost to the butter. These facts have suggested, and have led to the practice in some instances, of dispensing with cream ripening, and of working the desired aroma substance direct into the butter, thus eliminating much of the added operating expense, avoiding the quality-jeopardizing effect of high churning acidity, and preventing the waste of flavor principle. This may be done by mixing starter, starter distillate, or synthetic flavoring compounds with the butter during the working process.

Working Starter Into the Butter.—This is a common practice in many creameries. Instead of using water for wetting the salt and for bringing the moisture up to the desired point, several gallons of starter are added to the butter with the salt. The starter so used does assist in freshening the flavor of the butter

made from unripened cream somewhat. It does not increase the acidity of such butter sufficiently to augment the danger of deterioration due to chemical reactions. The keeping quality of butter so treated is similar to that of butter made from unripened cream without the addition of any starter. The resulting improvement in flavor, however, is slight. The butter still lacks the full aroma and flavor of ripened cream butter.

Working Distillate of Starter Into the Butter.—The process of distilling the butter flavor essences from the starter and adding them to the butter in the form of standardized starter distillate was developed by Ruehe,[49] whose method of preparation of the starter distillate is as follows:

Incubate the pasteurized starter milk that has been inoculated with the usual butter culture containing lactic acid bacteria and flavor organisms, at 70° F. for 24 hours. Then add 0.25 to 0.3% citric acid and incubate at 70° F. for another 24 hours.

Place the starter in a still which has steam and condenser connections. Add a small amount of ferric chloride ($FeCl_3$ oxidizes the acetoin to the aroma-producing diacetyl, greatly increasing the amount of diacetyl). Distill at the rate of 50 cc. distillate from 200 cc. starter. Standardize the resulting distillate to a definite diacetyl content and acidity. This distillate keeps at ordinary cooler temperature (40° F.) without appreciable loss of diacetyl.

For use in butter, add the distillate to the butter with the salt. Use the distillate at the rate of approximately 2 to 2.5 lbs. of distillate per 1,000 lbs. of butter.

Ruehe reports that butter flavored with starter distillate in the above, and even in larger amounts, "stood up" satisfactorily during storage for 14 months. There was no indication of impairment of keeping quality due to the distillate. He suggests, however, the necessity of further study before definite conclusions are justifiable.

Working Preparations of Synthetic Diacetyl into Butter.—The discovery by Van Niel, Kluyver and Derx[50] in 1929, of diacetyl as the principle source and cause of the characteristic aroma and flavor of butter, has been followed by the appearance on the market of diverse so-called butter cultures in the form of commercial preparations containing synthetically prepared diacetyl. Some of these preparations are clear concentrates of

diacetyl in milk, concentrated milk or other vehicles, still others contain, in addition to diacetyl, volatile acids, such as acetic, or propionic, or both.

Their use in amounts that confine the diacetyl content of butter to 4 p.p.m. or less, has not been found damaging to the chemical stability of butter, but when used in excessive proportions they may easily cause damaging oxidation of the butter fat, leading to bleaching and tallowy flavor, as shown by King.[44]

The addition of synthetic compounds of diacetyl obviously does give the butter some of the diacetyl type of aroma. In the absence of other aroma products that are normally associated with citric acid fermentation, such as volatile acids, CO_2, and probably acetaldehyde and other as yet undetermined volatile essences, which blend with the diacetyl aroma to give a composite effect of the characteristic, pleasing aroma of good butter, these commercial preparations containing synthetically prepared diacetyl only, give the butter a somewhat unnatural, harsh aroma character. The butter lacks the pleasing, mellow, blended aroma of ripened cream butter.

Furthermore, the mere working into the butter of these flavor compounds fails to fuse them with the butter constituents as completely as when they are produced and absorbed in the cream and churned into the butter. They do not become a truly integral part of the butter, and the aroma of such butter lacks permanency. After comparatively short storage the butter is relatively devoid of the aroma that it had at the churn.

In addition, these butter flavor compounds have no merit from the standpoint of retarding bacterial deterioration of butter. Their use, therefore, has no quality-stabilizing effect on unsalted butter, the keeping quality of which, being chiefly a bacteriological problem, is materially and definitely enhanced by cream ripening. This objection applies likewise to the use of starter distillate.

REFERENCES

1. MICHAELIAN, M. B., and HAMMER, B. W., Ia. Agr. Expt. Sta. Res. Bul. 179, (1935).
2. VIRTANEN, A. I., XI. World Dairy Cong. II, *2*, 121, (1937).
3. KRENN, J., XI. World Dairy Cong. II, *2*, 78, (1937).
4. MOHR, W., and WELLM, J., XI. World Dairy Cong. II, *2*, 89, (1937).
5. DAVIES, W. L., XI. World Dairy Cong. II, *2*, 76, (1937).
6. HUNZIKER, O. F., Addr. Am. Butter Inst. Chicago, (1937).
7. HUNZIKER, O. F., and CORDES, W. A., Blue Valley Res. Labs. (not publ.), (1924-26).
8. HUNZIKER, O. F., Addr. Ore. Dairy Short Course, Corvallis, (1935).

9. HUNZIKER, O. F., Ind. Dairy Tech. Club, Indpls., (1937).
10. ST. VON NYIREDY, XI. World Dairy Cong. II, *2b*, 137, (1937).
11. STORCH, V., Milch Ztg. 104, Apr. 16, (1890)
12. PATRICK, G. E., LEIGHTON, F. A., and HEILDEMAN, W. H., Ia. Agr. Expt. Sta. Bul. 21, (1893).
13. DEAN, H. H., 13th Ann. Rept. Ont. Agr. Coll., (1904).
14. GRAY, C. E., and MCKAY, G. L., U. S. Dept. Agr. B. A. I. Bul. 84, (1906).
15. CREDICOTT, H. J., Addr. First Ann. Nat. Dairy Show, Chicago, (1906).
16. SHUTT, F. T., and SHARON, A. T., Can. Dept. Agr. Bul. 13, (1907).
17. SOMMERFELD, P., Handbuch der Milchkunde, (1909).
18. ROGERS, L. A., U. S. Dept. Agr. B. A. I. Circ. 146, (1909).
19. ROGERS, L. A., and GRAY, C. E., U. S. Dept. Agr. B. A. I. Bul. 114, (1909).
20. THOMSON, G. S., Crosby Lockwood & Son, London, 136, (1913).
21. DAVIS, L. M., Cal. Agr. Expt. Sta. Circ. 60, (1911).
22. DAVIS, L. M., U. S. Dept. Agr., Farmers' Bul. 499, (1912).
23. ROGERS, L. A., THOMPSON, S. C., and KIETHLY, J. R., U. S. Dept. Agr. B. A. I. Bul. 148, (1912).
24. FLEISCHMANN, W., Lehrbuch der Milchwirtschaft, (1915).
25. DYER, D. C., J. Agr. Res. VI, 24, (1916).
26. HUNZIKER, O. F., Addr. Nat. Conf. Allied Dairy Industries, Washington, (1916).
27. HUNZIKER, O. F., Addr. Am. Ass. Cry. Butter Mfrs., Chicago, (1918).
28. HUNZIKER, O. F., The Butter Industry, 1st ed. 230, (1920).
29. GUTHRIE, E. S., N. Y. (Cornell) Agr. Expt. Sta. Bul. 173, (1916).
30. ROGERS, L. A., N. Y. Prod. Rev. and Am. Cry. *48*, 1004, (1919).
31. CUSICK, J. T., N. Y. (Cornell) Agr. Expt. Sta. Mem. 30, (1920).
32. MCKAY, G. L., and LARSON, C., Principles and Practices of Buttermaking, 3rd ed. (1922).
33. MORTENSEN, M., Ia. Agr. Expt. Sta. Bul. 207, (1922).
34. MORTENSEN, M., Rept. 9th Ann. Instit. Dairying, Wash. State Coll., (1936).
35. GRIMES, M., J. D. Sc. VI, *5*, (1923).
36. SOMMER, H. H., and SMIT, B. J., Wis. Agr. Expt. Sta. Res. Bul. 57, (1923).
37. WHITE, WM., TRIMBLE, C. S., and WILSON, H. L., U. S. Dept. Agr. Tech. Bul. 159, (1929).
38. HOLM, G. E., WRIGHT, P. A., WHITE, WM., and DEYSHER, E. F., J. D. Sc. XXI, *7*, 385, (1938).
39. DAVIES, W. L. XI. World Dairy Cong. II, *2b*, 124, (1937).
40. RITTER, W., Travaux de Chim, Aliment, et d'Hyg. XXVI, *3*/*4*, 145, (1935).
41. RITTER, W., XI. World Dairy Cong. II, *2b*, 162, (1937).
42. MOHR, W., and AHRENS, H., Molk. Ztg. Hildesheim, (1936).
43. MOHR, W., and RITTERHOFF, Molk. Ztg. Hildesheim, 28/29, (1938).
44. KING, N., Zeitschr. f. Milchkunde u, Milchw. XII 1 and 2, 172, (1931).
45. FERRIS, L. W., J. D. Sc. VI, *4*, (1923).
46. FERRIS, L. W., J. D. Sc. VI, *5*, (1923).
47. FERRIS, L. W., REDFIELD, H. W., and NORTH, W. R., J. D. Sc. IV, *6*, (1921).
48. RITTER, W., and STÜSSI, D., Schweiz. Zentbl. f. Milchw. XXIII, 6, Feb. 9, (1934).
49. RUEHE, H. A., Addr. Am. Butter Instit., Chicago, (1938).

CHAPTER XV.

CHURNING

Object of Churning.—The object of churning is to produce butter. It is to concentrate and convert that part of milk or cream which constitutes, and is commercially recognized as, its most valuable ingredient—the butter fat—into a form of food product—butter—that is less perishable and more suitable for economical disposition in its journey from cow to consumer.

Milk an Emulsion of Fat-In-Skim Milk.—When milk is secreted, nature places the fat which is liberated by the metabolic activity of the cells lining the alveoli of the mammary glands, into the milk serum in the form of finely divided particles of liquid fat—the fat globules. In freshly drawn milk the fat globules are suspended in the watery mixture of hydrated colloid emulsion which constitutes the skim milk. Whole milk thus represents an emulsion of fat-in-skim milk, the fat being the divided or dispersed phase, and the skim milk the continuous or dispersing phase. This emulsion, established by nature's handiwork, is fairly permanent. As long as it remains intact, butter does not form.

PERMANENCY OF FAT-IN-SKIM MILK EMULSION

The influences that enter into the permanency of the fat-in-skim milk emulsion are many and complex. Among the natural forces that underlie the creation and the permanency of the emulsion are the force of surface tension and the phenomenon of adsorption, assisted by the electric tension on the fat globules and the viscosity of the cream.

Surface Tension.—The presence of the fat in globular form is the result of the force of surface tension. By surface tension is commonly understood the tension of the surface film of a liquid, caused by the molecular attraction towards the interior. The molecules in the interior are attracted in all directions and are thus in equilibrium, while the molecules on the surface have no neighbors outside to balance the attraction of those within. The tension thus produced on the surface by the molecular

attraction towards the interior is called the surface tension. By virtue of this tension the surface always tends to contract to the smallest possible area. Hence, if the liquid is placed in a position where it is not affected by gravity, the form of the liquid changes until it assumes the minimum surface for a given volume, which is the sphere. By reason of its surface tension, therefore, the fat in milk is present in globular form and, unless its surface tension is disturbed by mechanical force or other means, the fat retains its globular form, and the fat globules retain their individuality.

Fig. 59. Seat of milk secretion
Courtesy of R. R. Graves, Bureau of Dairy Industry, U.S.D.A.

Absorption.—The structure and nature of the fat globules of milk have been subjected to extensive study for over a century. The earlier investigators held that the fat globules are surrounded by a definite, skin-like membrane. The results of later researches failed to substantiate this assumption, and have led to the general acceptance of the theory, that the surface layer of the fat globules is the result of adsorption. As here applied, adsorption refers to the attraction to and concentration on the surface of the fat globules of some of the non-fat constituents of the milk.

The phenomenon of adsorption finds its explanation in the physical law of Gibbs-Thomsen, that bodies which lower the surface tension of a medium will concentrate in the surface layer. Most of the proteins of milk are known to lower the surface tension. As a result, there is a tendency for these colloidal milk constituents to be attracted and held fast to the surfaces of the fat globules, surrounding each globule with a

thin film of condensed protein material, which further assists the fat globules in retaining their individuality, and in stabilizing the fat-in-skim milk emulsion.

The nature and composition of the material adsorbed to the surface of the fat globules has been the subject of extensive study by numerous investigators. As early as 1897 Storch,[6] by washing fat globules free from extraneous protein material, was able to isolate and analyze the contents of the adsorbed film. He found this adsorbed material to be of a mucoid protein nature, differing in composition from that of any of the milk proteins. He likewise showed that the serum of butter contains more of this material than the buttermilk.

The more recent work of Palmer and co-workers[7,8,9,10,11] who likewise studied the composition of the fat globule "membrane" after repeated washing of the cream with distilled water, corroborates the findings of Storch to the effect that the protein material adsorbed most closely to the fat globules is unlike that of the casein, albumin, and globulin of milk. They demonstrated that the adsorption "membrane" found on the fat globules of butter fat that was mechanically emulsified into sweet rennet-whey, skim milk, and buttermilk, respectively, did not have the same composition as the natural fat globule "membrane" of milk. Palmer and co-workers concluded that the material most closely adsorbed to the surface of the fat globules in cow's milk is composed of a mixture of protein and phospholipids; that the physical properties and the percentages of nitrogen, sulphur, and phosphorus do not correspond with those of any other milk protein; that the phospholipids are a mixture of mono-amino and di-amino compounds; that the protein constitutes the major part of the so-called fat globule "membrane"; and that a large part of the "membrane" material is removed during churning.

Völtz,[12] Abderhalden and Völtz,[13] and Titus, Sommer and Hart[14] on the other hand, who allowed the fat globules of cream to rise through long columns of water, assuming that by this treatment the fat globules were freed from cream serum, but retained the protective materials adsorbed to the fat surfaces, reported that all, or the principal constituent of the envelope around the fat globules was casein.

North and Sommer[1] concluded that two types of adsorption exist at the fat globule surface, one reversible and the other irreversible, and Jack and Dahle[15] suggest that the inner layer

of the fat globule "membrane" is phospholipin and the outer surface is composed chiefly of protein. Similar findings were reported by Bird, Breazeale and Bartle[5] who arrived at the hypothesis that two distinct protective materials are adsorbed to the fat globules, one being a phospholipin-protein complex lying most closely to the fat surface, which they adjudged non-labile (stable) because of the affinity of its fatty acid groupings for the fat of the globule and its consequent resistance to removal from the fat-water surface. The second material is located on the water-side of the fat globule surface. It is believed to be composed of all those constituents of the milk serum that lower the surface tension, but has been found to function in such manner as to indicate that casein is its most important constituent. This material is labile (unstable), passing readily from cream serum to fat globule surface and vice versa and is much more readily removed from the globule surface than the non-labile material.

Bird and co-workers[5] further hold that the protective materials do not cover the globule surface in the form of a continuous membrane, but are held at force centers; that the protein-phospholipid substance is irreversibly associated with the fat globule surface; and that this material must associate itself with the newly formed fat surface before the fat globule comes in contact with the milk serum, suggesting the association of cell protein-phospholipin complexes with the "nascent fat globules at the time of their formation and secretion. On the basis of this hypothesis Bird and co-workers hold that in the churning process, at the point when the fat globules are sufficiently closely packed in the foam lamellae, the attraction of those portions of the fat globules that are not covered by the non-labile membrane substance and from which the labile materials have migrated, assists in combining the fat globules into butter granules.

Electric Charge on Fat Globules.—A further force that keeps the fat globules in milk and cream from uniting into larger units has to do with their electric charge. Most substances when suspended in water assume a negative charge. This is true of the fat globules suspended in milk, as shown by North and Sommer[1] and Jack and Dahle.[2] Being similarly charged (electro-negative) the fat globules tend to repel each other and

this repulsion, unless counteracted by other forces, assists in keeping the fat-in-skim milk emulsion intact.

The charge on the fat globules is affected by the acidity of the cream. It diminishes as the acidity increases. The decrease in electric potential appears to be slight until the isoelectric point of casein (curdling point) about pH 4.7, or an approximate titratable acidity of .51%, is approached. From this point on the electric charge on the fat globules decreases rapidly. As the zero potential is approached, an increasing number of fat globules becomes positively charged, and this mixture of fat globules with positive and negative charges, respectively, has the effect of changing their electrical repulsion to attraction. This sharp decrease in electric charge has, in fact, been found to coincide with a drop in fat losses in the churning process. When the acidity of the cream reduces the electric potential to zero, a further rise in acidity is accompanied by an increasingly positive charge on the fat globules, augmenting the tendency of their repulsion, and this in turn coincides with an increase in the buttermilk test.

That there is a relationship between the charge on the fat globules and the churnability of cream has been shown by Mohr and Brockman,[3] Sommer and North,[4] and Bird, Breazeale and Bartle.[5]

Viscosity.—By viscosity of a liquid is meant its resistance to flow. It is the reciprocal of fluidity and constitutes an inherent property of all liquids. Milk is more viscous than water at the same temperature, and cream is more viscous than milk. The viscosity of milk is affected by many factors, such as concentration of fat and solids not fat, temperature, agitation, changes in the physical state of the fat phase and of the colloidally dispersed phases. It is generally conceded that the casein contributes more to the viscosity of milk than do any of the other ingredients. According to Holm,[16] fat in concentrations found in normal milks contributes less than does casein, but more than does albumin.

The viscosity of milk is a factor that lessens the tendency of agglomeration and adhesion of the fat globules to each other. It functions in the direction of enhancing the permanency of their dispersion and of the fat-in-skim milk emulsion. In the churning process, therefore, an increase in viscosity tends to

retard the formation of butter granules, while a decrease in viscosity tends to shorten the churning time.

Effect of Cream Separation on Fat-in-Skim Milk Emulsion.—When milk is separated, the resulting cream differs from the original milk chiefly in that the concentration of fat has been increased from about 3-4% present in the milk to about 25-40% present in the cream. Cream merely represents a larger aggregation of fat globules, in a smaller volume of skim milk.

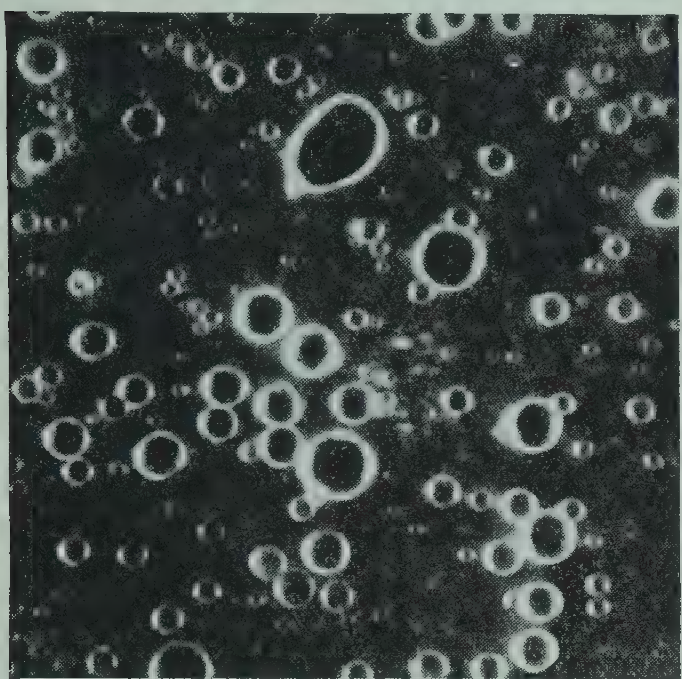


Fig. 60. Fat globules in milk
(Magnified X 740)

The character and composition of the colloidal, continuous phase, the serum of the cream, are similar to those of the original milk, with perhaps a slightly increased concentration of the milk albuminoids. The fat still represents the dispersed phase. The forces of surface tension, adsorption, electrical potential, and viscosity continue to function similarly as in milk. Cream, like milk, is an emulsion of fat-in-skim milk.

The higher fat content of cream, resulting in a greater density of fat globules, however, does have the effect of promoting more profuse coalescence and aggregation than is the case in the original milk. This fact, together with the phenomenon shown by Rahn and Sharp,[17] that the very small fat globules (measuring less than 2 microns) are not removed by centrifugal separation and, therefore, fail to appear in the cream, causes the cream to contain a larger proportion of large fat globules and larger fat units than the original whole milk.

Effect of Heat and Agitation Upon Size and Dispersion of Fat Globules.—Agitation of milk or cream brings the fat globules in contact with one another. At ordinary temperature this contact results in their tendency to adhere to each other, or coalesce, forming larger aggregates or clumps. This tendency of the fat globules to coalesce and to form clumps increases as the temperature drops. According to Weinlig,[18] below 65° C

(149° F.) clumping increases with lowering temperature and at 7 to 8° C. (44.6-46.4° F.) the clumping is at its maximum.

Agitation at temperatures above the melting point of butter fat tends to cause subdivision of the fat globules and of the fat aggregates. This effect increases with rising temperature, and

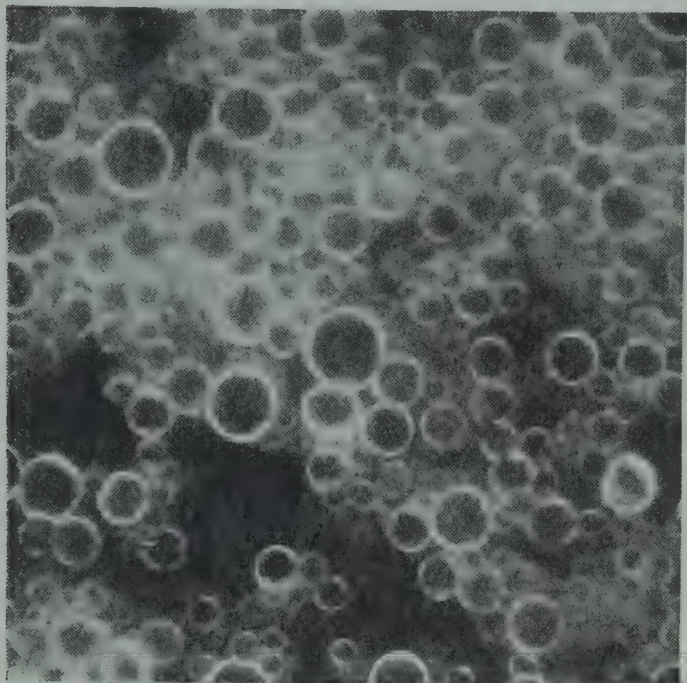


Fig. 61. Fat globules in cream
(Magnified X 740)

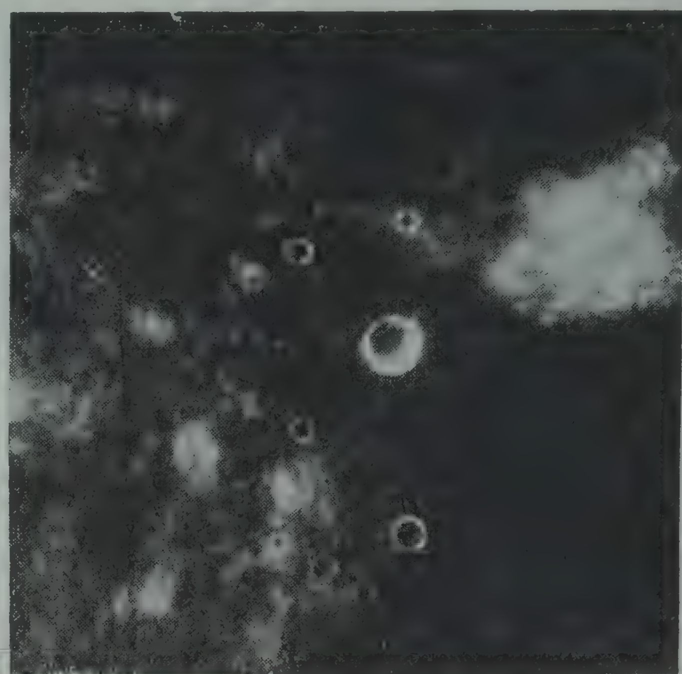


Fig. 62. Fat globules in skim milk
(Magnified X 740)

is especially pronounced at temperatures such as are commonly used in pasteurization. This tendency of cleavage, when milk or cream is agitated while heating, is greatest in the case of the large size fat globules. There is comparatively little, if any, subdivision of the medium size and small globules. Rahn and Sharp[17] show that it is especially the globules with a diameter in excess of 6 microns, that are prone to split up into medium size globules (dia. 3 to 6 microns). Milk and cream heated under agitation, therefore, usually is relatively free from large fat aggregates, the large fat globules have mostly disappeared, and the medium size and small globules are vastly predominating.

The manner and duration of heat treatment and agitation are important factors in determining the effect on fat dispersion. Prolongation of treatment, such as may occur in connection with recirculation in the process of cream deodorization, for instance, yields an entirely different microscopic picture of the cream. As observed by Hunziker,[19] the tendency in this case is for the large and medium size fat globules to run together, forming large units of melted fat with irregular contour. Such cream usually shows an almost complete absence of medium

size globules, and a mixture of a multitude of very small globules and of isolated blotches of very large units of butter oil. When cream of this character is cooled, there is danger of premature churning, and of the appearance of mealiness in the resulting butter.

Effect of Cooling the Cream Preparatory to Churning.— When cream is cooled preparatory to churning, the fat in the fat globules undergoes partial solidification. The degree of solidification of the fat in the cream plays an important part in the churning process and it determines, in a large measure, the firmness and standing-up properties of the body of the butter.

In order to make possible the formation of butter, at least partial solidification of the fat is necessary. Solidification that will make possible the formation of butter need not necessarily occur in the cream before churning, as the concussion to which the cream is subjected in the churning process, itself, causes partial solidification of the fat in the fat globules, provided that the temperature of the cream is below the melting point of the fat. The churning of uncooled cream, however, is accompanied by such high fat losses, and yields butter of so unsatisfactory (weak) a body, that it is economically prohibitive.

Cooling the cream to an abnormally low temperature, such as to near the freezing point of water, on the other hand, renders the fat globules so firm that they adhere to each other with difficulty, if they coalesce at all, greatly prolonging the churning process. In the case of thin cream with small fat globules butter may not form at all.

High cooling temperatures of the cream shorten the churning period, yield large losses of fat in the buttermilk and produce butter with a relatively soft body that does not stand up well under unfavorable temperature conditions. Low cooling temperatures prolong the churning period, decrease the fat losses in the buttermilk and produce a firm body that has satisfactory standing-up properties. Thoroughly chilled cream may be warmed to moderate ripening temperature without serious danger of impairing the body of the butter or of excessive fat losses in the buttermilk.

Under average conditions the results relative to body of butter and exhaustiveness of churning are benefited by holding the cream at the cooling temperature for several hours (at least

two hours) before churning. For holding over night a slightly higher cooling temperature than for short holding (2 to 4° F. higher) is adequate.

Cooling cream of average richness (about 28 to 35% fat) to a temperature that will cause it to churn out within approximately 30 to 45 minutes, usually yields a butter of satisfactory firmness and reasonably low fat losses. The optimum temperature to which to cool cream for best results depends primarily on the composition of the butter fat and must, therefore, vary with the seasonal changes of this factor. It is also affected, though to a lesser extent, by the size of the fat globules and the richness of the cream. In addition to these seasonal and local factors that are not under the control of the buttermaker, such factors as length of time the cream is held cold, temperature of ripening and of churning, acid reaction of the cream and the status of dispersion or precipitation of the casein enter into the relation of cooling temperature and churning results.

In general, and taking into consideration all normal variations of conditions and factors, the proper adjustment of the cooling temperature within a range of about 40 to 56° F., provides a degree of solidification of the fat in the cream that may be expected to yield a normal churning period and to insure reasonably exhaustive churning, and a satisfactory firmness of body.

Considering the relation of churning period to exhaustiveness of churning, it might be consistently expected that the factors that facilitate the churning process (and therefore shorten the churning period), also enhance the exhaustiveness of churning. The logic of this reasoning is undeniable and it is supported by practical experience, to the extent that under certain combinations of conditions that cause an abnormally long churning period, such as for instance much in excess of 60 minutes, the fat losses are prone to be excessively high. And again, there are occasional churnings that churn out abnormally quickly, and that are accompanied by small fat losses in the buttermilk.

On the other hand, under all normal conditions, practical observations have amply demonstrated that minimum fat losses are usually associated with longer rather than with shorter churning time. This fact is due to the predominating influence of the degree of fat solidification, which associates excessive fat

losses with abnormally short churning, and minimum fat losses with longer churning.

Theoretical Considerations of Cream Cooling.—Van Dam,[20] as the result of extensive study of the relation of fat solidification to the churning process, concluded that minimum fat losses in the buttermilk are possible only when a state of equilibrium (complete solidification) has been produced in the fat system. He further showed, by dilatometer measurements of the expansion of the fat resulting from warming cream that had been cooled to different temperatures, that in order to produce fat equilibrium, cream must be held for a prolonged period of time (21 hours) at about 10° C. (18° F.) below the churning temperature.

On the basis of Van Dam's findings, and of our present knowledge of the science and art of buttermaking, it appears obvious that the attainment of a fat equilibrium that represents complete solidification of all the fat in the cooled cream is, under conditions of practical butter manufacture, neither feasible, necessary, nor desirable. Van Dam's work has demonstrated that the fat in the cream that has been cooled preparatory to churning is in fact present, not in a state of equilibrium (complete solidification), but occurs in partly crystalline and partly liquid form.

This conclusion is supported by the later work of Arup[21] and of Quagliariello,[22] who demonstrated the presence of liquid fat in cream cooled to temperatures to and below 10° C. (50° F.). Further tangible evidence of a liquid fat phase in butter is offered by the work of King,[23] whose study of the inversion of phases from fat-in-water in cream to water-in-fat in butter, calls attention to the liquid fat portion as the continuous phase in butter. Van Dam and Burgers,[24] likewise, established the presence of liquid fat in butter by X-ray examinations.

The extent to which fractional crystallization takes place and the proportion of crystallized and liquid fat present in cream cooled to any given temperature depend largely on the composition of the butter fat and this, in turn, is subject to a wide range of local and seasonal variations due to breed, period of lactation and feed.

The effect of these variations in composition is further complicated by the fact that butter fat is a mixture of at least nine different fatty glycerides which vary widely in their respec-

tive melting points (from 150° F. in the case of stearin to 96° F. below zero in the case of tributyrin); that it is not definitely known which of the fats are present as single triglycerides, which are present as composite triglycerides and in what combination of fatty acids; and that the composite melting point of a mixture of two or more fats of known individual melting points, cannot be predicted. For details on composition of butter fat see Chapter XXI.

Aside from the effect of the relative degree of solidification of the fat in the cooled cream (proportion of solidified to liquid fat) on the firmness of the butter, the size of the fat crystals is a factor entering into the determination of the texture of the firmness produced, whether pliable, plastic and waxy, or crumbly and sticky. For details see "Seasonal Defects of Body and Texture" Chapter XXIII.

Effect of Agitation in Churn.—The concussion to which the cream is subjected in the churn assists in bringing the fat globules in intimate contact with one another, and provides the force of impact that facilitates their adhesion. The continuous agitation taking place in the churn, therefore, results in coalescence of the fat globules and in the formation and progressive growth of clumps.

As previously shown, the rapidity of this churning is primarily dependent upon the degree of solidification of the fat and, therefore, on the temperature of the cream. Likewise, the concussion in the churn itself promotes fat crystallization. Storch[6] observed a tendency for the violent agitation produced in the churn to disturb and partly disrupt the film of protein material that is adsorbed to the surfaces of the fat globules, and he holds that the resulting exposure of free fat facilitates adhesion and clumping. The rupture of the protective coating of the fat globules is supported by the findings of Palmer and Wiese[9] who report that a large part of the fat globule "membrane" material is removed during churning.

The union of fat globules thus appears to proceed in something like geometric progression. While it probably commences as soon as the churning agitation is started, the process of uniting at first is necessarily slow and the change is imperceptible. As the churning process progresses, the formation of clumps and their increase in size gain momentum with each successive coalescence of fat globules and of clusters of fat

globules. See also Bird and co-workers' theory of labile and non-labile protective materials on the fat globules under "Adsorption" earlier in this chapter.

Why Cream Thickens in Churn.—It is a matter of common observation that an increase in the particle size of the dispersed phase of an emulsion causes the liquid to thicken. The thickening of milk due to the precipitation (curdling) of the dispersed casein is a convincing example of this phenomenon. Similarly in the churning process, the growing particle size of the fat units causes progressive thickening of the cream. In fact, this thickening continues until the cream assumes marked rigidity. This is due, in part at least, to the increased internal resistance of these larger aggregates, holding the watery phase in a mash-like emulsion.

This thickening is further accentuated by the profuse incorporation of air during the churning process. It was shown by Rahn[25] that when air is blown into milk, the fat may be recovered from the foam. This suggests that the fat globules aggregate and are held in the foam cells (air-serum interfaces). Thus, air beaten into the cream in the churn may, and probably does, provide added means for bringing the fat globules into reciprocal contact and for enhancing the rate of aggregation and coalescence.

Excessive Foaming Retards Churning.—While the churning of cream is invariably accompanied by foaming and while, under normal conditions, the establishment of foam precedes the breaking point of the cream, excessive foaming has a marked retarding effect on the churning process. In extreme cases the foam may swell the cream to a point that causes the foamy cream to completely fill the churn, stopping concussion entirely, rendering the formation of butter impossible, and necessitating removal of a portion of the cream from the churn in order to complete the churning process.

Such abnormal foaming is usually due to excessive viscosity of the cream, yielding abnormally tough walls of the foam cells, that resist distortion and rupture. This situation may arise in the case of very cold cream, or cream that has undergone ropy-milk fermentation, or cream from stripper cows due to the formation of soap from fatty acids liberated by phospho lipids, as suggested by Palmer.[26]

For similar reasons, any agency or condition that reduces the viscosity of the cream, intensifies concussion, facilitates the uniting of the fat globules, augments the clumping and hastens the churning process. Thus, sour cream churns more readily than sweet cream, the acid destroying the viscosity and the whipping property of the cream. Cream from cows in early lactation churns more rapidly than cream from stripper cows, because the former is more fluid and less viscous, contains larger fat globules that are more sensitive to concussion, and is freer from lipolipids thereby minimizing the tendency of setting free fatty acids and inducing the formation of soap. Cream churns more quickly at a relatively high temperature than at an excessively low temperature, because the former has greater fluidity, foams less, produces more readily collapsible foam walls and gives the fat globules greater adhesive property.

Why Butter "Breaks" Suddenly.—As the fat aggregates in the thickened cream grow larger in size, a point is reached where their surface area becomes so small in proportion to their cubical contents, that the fat-in-skim milk emulsion can no longer be sustained. The skim milk (now called buttermilk) that is present in excess of that which is incorporated into the butter granules and that which adheres to their limited surface area, recedes, the emulsion breaks, the butter granules separate out, the butter has "come." That a definite surface area of the water phase is necessary to break the fat-in-skim milk emulsion is further indicated by the constancy of the ratio of water to fat in different butters (before working) churned under identical conditions, as pointed out by Holm[16] and also observed by Hunziker.[30]

Under average, normal conditions, the churning process occupies from about 30 to 60 minutes, yet the actual "breaking" of the emulsion, the visible "coming" of the butter, happens with almost instantaneous suddenness. Suddenly the churn load increases and more power is required to operate the churn. Shortly following this increase in load, the cream begins to break away from the spy glasses of the churn and they soon become almost perfectly clear.

This appears to be the visible "breaking point" of the cream at which the butter actually "comes." Examination of the contents of the churn now reveals the presence of very small butter granules, of the size of pinheads. A continuation of the churn-

ing process brings these minute granules together into larger granules of the desired size.

The transition from cream to butter constitutes an inversion of the phases of the emulsion. With the "coming" of the butter the emulsion changes from a fat-in-water (skim milk) emulsion as represented by the cream, to a water (buttermilk)-in-fat emulsion as represented by the butter.

Churning Theories.—The mysteries of the churning process and of the formation of butter have been the subject of extensive research by numerous investigators. While this study has resulted in several, somewhat diverging theories, and while there still is room for reasonable doubt regarding some of the forces involved, and their relative importance, this work has yielded much information of scientific interest and some facts of practical value, regarding the mechanism of the process.

The Phase-Inversion Theory.—The theory that the churning process involves a reversion of phases, changing from the fat-in-water emulsion (cream) to a water-in-fat emulsion (butter) was first advanced by Fischer and Hooker.[27] That the water (buttermilk) in butter is no longer the continuous phase, but is present in the form of minutely dispersed droplets, is a fact definitely and conclusively established by microscopic examination of butter. The theory that the fat in butter is the continuous phase in which the water droplets are dispersed, is based on the belief that the "membrane" adsorbed to the surface of the fat globules is disrupted by the churning process, causing liberation of some of the fat, facilitating fat coalescence and simultaneous dispersion of buttermilk droplets in this free fat. The dispersion of the moisture droplets in the free fat and the resulting water-in-fat emulsion are facilitated by the fact that the free fat phase consists largely of semi-liquid and liquid fat, as shown by King.[23]

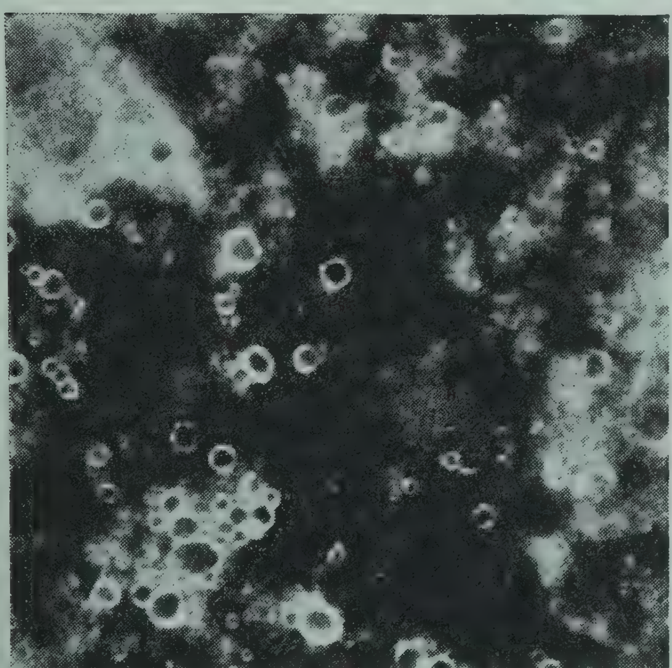


Fig. 63. Fat globules in buttermilk
(Magnified X 740)

Fischer and Hooker look upon the mechanism of butter

formation as a progressive coalescence and clumping of the fat globules, occurring in geometric progression until the ratio of surface area of the fat units to their cubical contents, becomes so small that this reduced surface area is no longer capable of retaining all of the liquid (skim milk), causing the emulsion to break.

The Foam Theory.—This theory was advanced by Rahn,[25] who holds that the fat globules gather in the foam caused by the air dispersed in the cream during the churning process. The protein, lowering the surface tension, must accumulate in the newly produced surfaces, i.e., the foam membranes, and, on the assumption that the same protein material surrounds the fat

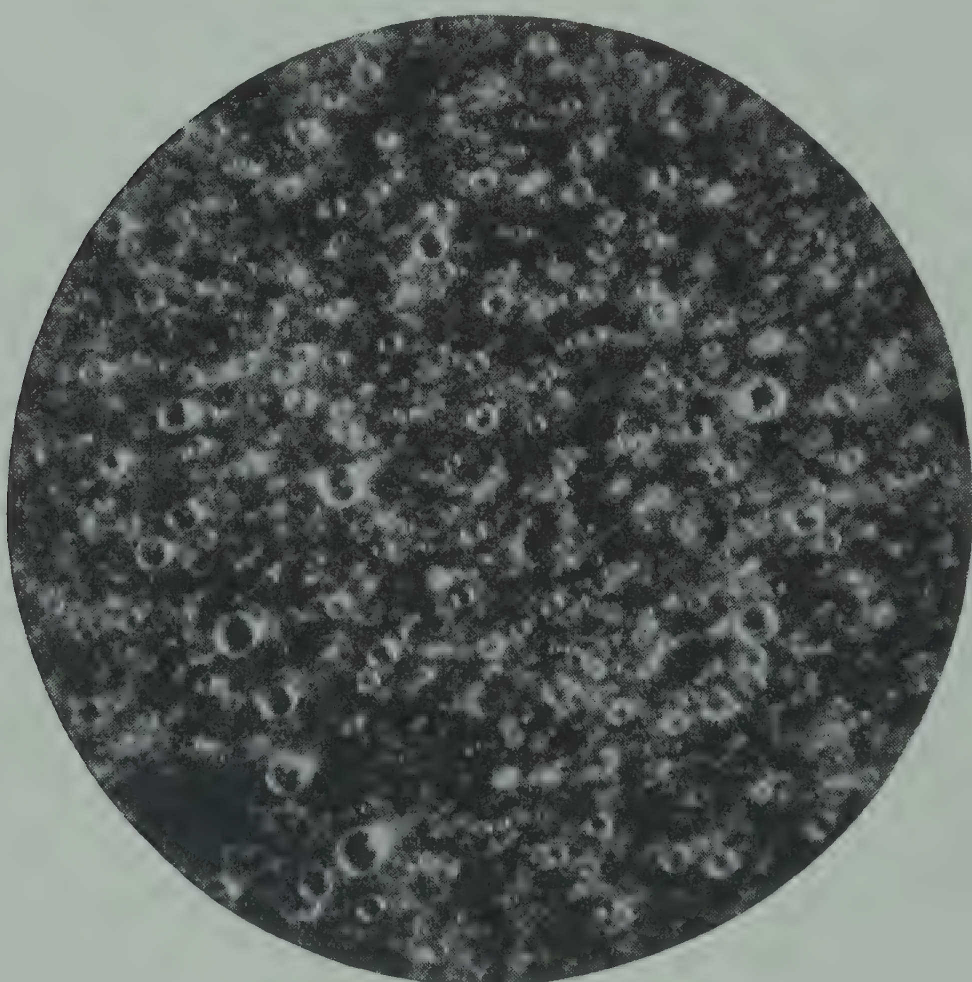


Fig. 64. Moisture droplets in butter
(Magnified X 740)

globules, they are drawn into the foam and held there. Lying close together, clusters form. The pressure between the foam walls packs these clusters into lumps, the lumps stick together and thus the fat units increase rapidly in size. When these lumps become so large as to disturb the surface equilibrium, or because the protein in the foam membranes solidifies, the foam collapses, and the butter "breaks." Rahn considers the fat in the cream at churning time as completely solidified, and the fat globules with their adsorbed "membrane" intact, looking upon

butter formation mainly as a packing together of the globules into a compact mass in the interfaces of which are enmeshed the water and air during the agitation in the churn. The fat globules having retained their original status, therefore, there is no free fat, hence the fat is not the continuous phase.

Merits of Churning Theories.—That butter contains fat globules that have preserved their individuality and their surface "membrane" has been demonstrated by the early work of Storch,[6] as well as by Rahn,[25] and by King.[23,28] Storch further showed that some of the fat globule "membrane" is disrupted and removed during the churning process, and Palmer and Wiese[9] found fat globule "membrane" material in the buttermilk. It appears probable, therefore, that the fat in butter is present in both, globule form and as free fat. This probability is further supported by the fact that the fat in cream is not present in a state of complete solidification, and by the work of King,[23] and of Van Dam and Burgers,[24] who showed the presence of a liquid fat phase in butter.

In this discussion of reversion of emulsion, the relative behavior in pH determinations of high-fat, reseparated cream and of butter of the same fat content, as determined by Hunziker,[29] is of practical significance. Normal cream was reseparated in a manner to yield reseparated cream containing 80 to 82% fat. Electrometric pH determinations were made, using the Quinhydrone electrode. This cream yielded perfectly normal pH values, indicating that, in spite of the abnormally high fat content that gives such cream every outward appearance of butter, the electrolyte (the water) still is the continuous phase and such cream still represents a fat-in-water emulsion. Butter with the same or any other fat content, as is well known, completely fails to respond to all attempts at pH determinations, no voltage being produced whatsoever, indicating clearly that the water here cannot be the continuous phase. Absence of any voltage between electrodes inevitably suggests the fat as the continuous phase, since the fat is devoid of electrolyte properties.

The several facts brought out in the foregoing citations appear to confirm the conclusion of Holm,[16] supported by King, that "Butter consists of fat globules, air bubbles and water droplets, each surrounded by protective films, and dispersed as it were, throughout a mass of free fat."

FACTORS INFLUENCING CHURNABILITY OF CREAM AND BODY OF BUTTER

Classification of Factors.—The ease with which cream churns, the exhaustiveness of churning and the firmness of the resulting butter depend further on many varying factors. Some of these factors have to do with the initial character of the cream and of its individual constituents, while others refer to conditions in the process of manufacture. To the former belong such dominating factors as chemical composition of the butter fat, size of fat globules, and viscosity of cream. The second group includes such factors of operation as temperature, richness and acidity of cream, fullness, nature of agitation, and speed of churn. The following schematic classification may serve to illustrate the interrelation of these numerous factors to each other and their effect on the churning process.

Influence of Chemical Composition of Butter Fat.—Butter fat is a mixture of numerous fatty glycerides with widely varying melting points, solidifying points and other fat constants. The effect of the chemical composition of butter fat on the churnability of cream and on the body of the butter relates largely to the proportion of soft fats (fats with low melting point) and hard fats (fats with high melting point) present. This, in turn, determines the degree of fat solidification in the cooled cream. In the absence of proper adjustment of the cooling temperature of the cream to compensate for fluctuations in the composition of the butter fat, an increase in the proportion of soft fats shortens the churning period, diminishes the firmness of the butter and increases the butter fat losses in the buttermilk; a decrease in the proportion of soft fats prolongs the churning period, increases the firmness of the butter, and decreases the fat losses in the buttermilk. In order, therefore, to attain the degree of fat solidification necessary for optimum results, the cooling temperature of the cream must be adjusted to the major fluctuations in the relative proportion of soft and hard fats.

Effect of Tributyrin and Olein.—The principal soft fats in the butter fat compound are the tributyrin and the olein. The former has an extremely low melting point (96° below zero F.). Olein likewise is liquid at ordinary temperatures (melting point 41° F.). The melting points of the majority of the remainder

of the fats are well above room temperature. These are classed as hard fats.

Because of its extremely low melting point, fluctuations in the amount of tributyrin may be expected to have a greater influence on the firmness of the butter than those of olein. However, tributyrin constitutes only a small fraction (about 3.8%) of the composition of butter fat, and its percentage is believed to fluctuate between comparatively narrow limits.

Correlation of Iodine Number to Hardness of Butter.—The Iodine number is indicative of the olein content. Olein makes up approximately one-third (about 35%) of the total butter fat, and its quantitative limits are known to fluctuate within a comparatively wide range (30-50%). It may reasonably be expected, therefore, that olein plays a dominating role in the determination of the softness or hardness of the butter fat mixture and of the butter.

This is, in fact, the case, as has been conclusively shown by the work of Hunziker, Mills and Spitzer,[31] Hagelund, Wode and Olsson,[32] Coulter and Hill,[33] Brouwer,[34] Hansen and Steensberg,[35] Lyons,[36] and Hilditch and Sleightholme.[37] The results of these investigators show a definite correlation between the olein content (as expressed by the Iodine number) and the hardness of butter fat and butter. Increases in the Iodine number are practically invariably associated with decreases in hardness and a drop in melting point, while decreases in the Iodine number are usually accompanied by increases in hardness and a rise in melting point. The effect on the melting point values, however, is less marked and less consistent.

Limited Correlation of Reichert-Meissl Number to Hardness of Butter.—The volatile fatty acids of which tributyrin is one of the major glycerides, are determined by the Reichert-Meissl number. An increase in the Reichert-Meissl value suggests an increase in tributyrin, and is, therefore, expected to be accompanied by a decrease in the hardness of the butter fat and butter, because of the extremely low melting point of tributyrin. In general this is the case with very abnormal fluctuations in the Reichert-Meissl number, but it does not apply so consistently to fluctuations within a normal range. As a whole, minor variations in the Reichert-Meissl value fail to show a consistent or significant influence on the hardness of butter.

CONDITIONS INFLUENCING THE CHURNABILITY OF CREAM

The churnability depends on

- Degree of solidification of fat. This is influenced by
  - Chemical composition of fat
    - Breed → Locality
    - Lactation → Season
    - Feed
      - Locality
      - Season
  - Temperature of fat
    - Cooling temperature of cream
    - Time held
    - Churning temperature
  - Concussion of cream
    - Agitation in churn
      - Design of churn
      - Fullness of churn
      - Speed of churn
    - Viscosity of cream
      - Lactation
      - Acidity
      - Age
      - Richness
- Coalescence of fat globules. This is influenced by
  - Mechanical firmness of fat
    - Chemical composition of fat
      - Breed → Locality
      - Lactation → Season
      - Feed
        - Locality
        - Season
  - Size of fat globules
    - Breed → Locality
    - Lactation → Season
  - Concussion of cream
    - Agitation in churn
      - Design of churn
      - Fullness of churn
      - Speed of churn
    - Viscosity of cream
      - Lactation
      - Acidity
      - Age
      - Richness

Thus, Coulter and Hill[33] concluded that within a range of Reichert-Meissl values of 25-28, the hardness of butter fat may vary without regard to the Reichert-Meissl number, while variations beyond this range appear to be correlated with the hardness. Likewise Monti[38] reported considerable difficulty in manufacturing butter from cream with abnormally low Reichert-

Meissl number, and Stout[39] also concluded that "there seems to be a direct relationship between the content of volatile components (Reichert-Meissl number) and body and texture of butter." These findings are in general agreement with the earlier results of Hunziker and co-workers.[31]

The limitations and variations of the influence of the Reichert-Meissl number on hardness may be due in part to its usually relatively narrow range of fluctuations, but probably more to the fact that fluctuations of the Reichert-Meissl number may involve variations in the volatile fatty acids other than tributyrate, some of which are known to have relatively high melting points, thus offsetting, wholly or in part, the hardness-diminishing effect of tributyrin.

A further cause contributing to the observed lack of correlation between Reichert-Meissl number and hardness may have to do with the fact that the majority of the factors that are known to influence the composition of the butter fat, affect the Reichert-Meissl number and the Iodine number in opposite directions, often causing an increase in the Reichert-Meissl value to be accompanied by a decrease in the Iodine number, and vice versa. The experimentally established predominating influence of the Iodine number on melting point and on hardness thus may overshadow or negate the lesser effect of the Reichert-Meissl number.

Factors That Influence the Composition of Butter Fat.—The chief known factors that influence the proportion of low and high melting point fats (soft and hard fats) in cream are breed, period of lactation and feed.

Effect of Breed.—The relative firmness of the butter made from the cream of three major breeds is shown in Table 27.

Table 27.—Showing Effect of Breed on Physical Firmness of Butter and Relation of Firmness to Butter Fat Constants[31]

Breed	No. of Cows	Reichert-Meissl No.	Iodine Number	Melting Point, °C	Depression mm.*
Ayshire.....	3	27.84	35.64	34.1	16.83
Holstein.....	3	27.56	37.10	34.3	4.88
Jersey.......	18	31.12	29.10	34.5	1.83

*The "Depression" shows the extent to which butter at a definite temperature yields under a definite weight. The greater the "Depression" the softer the butter.

Similar results were reported by Eckles and Shaw.[40] On the basis of these results the Jersey cows produced butter with a higher melting point and a firmer body than either the Holsteins or the Ayrshires. These results are consistently reflected by the Iodine number (olein), which was lowest in the case of the Jersey fat. It is significant, also, that the Jersey fat yielded the highest Reichert-Meissl number (volatile fats), indicating, as previously pointed out, that the iodine number has the dominating effect on the hardness of butter and butter fat and that fluctuations in hardness may, and frequently do occur, without relation to the Reichert-Meissl number.

While data regarding the relationship of fat constants and hardness of butter fat from the Guernsey breed are not available, the general character of the milk, cream and butter from this breed suggest it to be similar to that of Jersey butter fat. The high Iodine number and relative softness of butter from Holsteins and Ayrshires suggest that in localities where these breeds predominate, the cream is preferably cooled to and churned at a somewhat lower temperature than is suitable in localities where the Channel Island breeds predominate.

Effect of Period of Lactation.—The period of lactation has a very marked effect on the composition of the butter fat, as shown by the results of Hunziker, Mills and Spitzer,[31] given in Table 28. In order to eliminate the feed factor, the cows used in this experiment received the same feed ration throughout their respective periods of lactation.

Table 28.—Effect of Period of Lactation on Butter Fat Constants

Period of Lactation	Reichert-Meissl No.	Soluble Acids %	Insoluble Acids %	Iodine Number	Melting Point °C
1st month....	34.55	7.80	87.01	32.08	35.2
2nd month....	32.62	7.50	87.37	32.15	35.2
3rd month....	31.57	7.34	87.45	31.67	35.4
4th month....	31.89	7.34	87.34	32.00	35.2
5th month....	31.59	7.24	87.41	32.30	34.7
6th month....	31.39	7.19	87.57	32.78	34.1
7th month....	30.39	6.97	87.70	34.74	34.5
8th month....	28.48	6.55	88.00	35.90	34.7
9th month....	28.72	6.56	88.00	35.23	34.7
10th month....	29.72	6.69	87.78	33.72	34.0

The fat constants listed in Table 28 show that the Reichert-Meissl number (volatile fats) and the soluble acids were highest at the beginning of the period of lactation, decreased rapidly during the first three months, then remained constant to the sixth month, followed by another decisive and sustained decrease to the 9th month. The iodine number was lowest during early lactation and increased up to the ninth month, followed by a drop during the tenth month. The melting point followed inversely the Iodine number, demonstrating again the close relation between Iodine number and melting point. Arup[41] reported a similar effect of lactation on fat constants; advancing lactation increased the iodine value and decreased the Reichert-Meissl number.

These results further bring out the significant fact that the high iodine number, low melting point and soft butter characteristic of butter made during late spring and early summer, are not due to the period of lactation. Since the majority of cows in this country freshen in the spring, the effect of the period of lactation, as based on the results shown in Table 28, would be for summer butter to be firm and winter butter soft. That the contrary is the case is indicated in Table 29, which shows the Iodine number to be high and the melting point to be low during the summer months, and the reverse during the winter, with the inevitable result of firm butter in winter and soft butter in summer. This corresponds with the practical experience of the buttermaker. A comparison of Tables 28 and

Table 29.—Effect of the Season of the Year on the Composition of Butter Fat of Creamery Butter. (Hunziker et al[31])

	Reichert-Meissl No.	Iodine Number	Melting Point °C
January	30.03	31.20	33.4
February	30.58	31.97	33.5
March	31.30	31.94	33.5
April	29.35	35.83	33.3
May	29.55	36.48	32.5
June	29.56	38.23	32.45
July	28.90	37.10	31.9
August	27.13	38.99	32.1
September	27.19	35.36	33.0
October	26.54	34.27	33.2
November	28.36	30.65	33.4
December	29.62	30.30	33.6

29 is convincing evidence that the period of lactation is not the cause of the seasonal change from hard winter butter to soft butter in summer, and that the dominant cause, therefore, must lie in the change from dry feed in winter to pasture in summer.

The above results on the effect of the season on the iodine number and melting point are in agreement with the later findings of Stout and Stein,[52] and of Stout,[39] who reported that the iodine number was highest and the melting point lowest during the months of May, June, July and August, while the reverse occurred during the months of November, December, January and February. They found a higher Reichert-Meissl number in summer butter than in winter butter, however.

Effect of Feed.—The most important and most decisive factor influencing the composition of the butter fat and the tex-

Table 30.—Effect of Dry Feed versus Blue Grass Pasture on the Firmness of Butter and Its Relation to the Butter Fat Constants (Hunziker, Mills and Spitzer[31])

May	Reichert-Meissl No.	Iodine Number	Melting Point °C	Average Volume of Fat Globules	Depression mm.
8–14 Dry feed	30.24	29.97	34.5	39.48	.655
	30.47	29.51	34.5	40.00	.500
	30.56	29.34	34.3	45.11	.540
	30.40	29.11	34.5	48.44	.580
	30.14	28.67	34.3	61.49	.580
	30.15	29.50	34.4	49.31	1.040
	30.00	29.00	34.3	51.01	1.000
Average.......	30.28	29.30	34.4	47.83	.701
15–21 Dry feed plus one to two hours pasture daily	30.85	29.11	34.3	52.02	1.000
	30.77	29.33	34.4	51.92	1.080
	31.03	29.55	34.2	50.59	.955
	30.86	30.05	34.4	54.93	1.580
	31.20	30.36	34.3	75.62	1.665
	30.62	31.84	34.2	70.64	1.415
	30.93	33.12	33.8	76.01	3.080
Average.......	30.89	30.48	34.2	61.68	1.539
22–28 Pasture exclusively	29.96	33.51	33.5	76.04	4.165
	28.83	36.43	33.5	82.87	8.580
	28.66	38.06	33.4	93.83	3.915
	28.87	38.86	33.6	67.32	5.915
	27.57	38.97	33.2	60.60	6.832
	29.65	38.92	32.9	55.55	7.705
	28.59	39.36	33.1	62.12	5.830
Average.......	28.87	37.73	33.3	71.19	6.135

ture and firmness of the butter, is the feed. A vast amount of experimental work has been done on this subject in dairy countries located in various regions of the globe.

In general, green forage, such as green blue grass pasture, green mixed pasture grasses, green clover, green alfalfa, green coarse fodder, yield a high iodine value, low Reichert-Meissl number, low melting point and soft butter. Conservation of these green forage plants in the form of dry hay lowers the iodine number, raises the melting point and makes harder butter. Therefore, a change from dry winter feed to green spring pasture usually increases the iodine number, lowers the Reichert-Meissl number and the melting point, and yields a softer butter, while a change from green pasture to dry winter feed has the opposite effect. This effect of change from winter feed to pasture is shown in Table 30, as well as by similar results obtained by Dean and Hilditch,[42] Brouwer,[34] Hansson and Olofsson,[43,44] Coulter and Hill,[33] Arup,[45] and others.

The above table shows that the change from all-dry feed (winter feed) to all-pasture (summer feed), increased the average iodine value by 8.40 and the depression (decrease in hardness) by 5.43 mm. There was an average drop in melting point of 1.1° C. and in Reichert-Meissl number of 1.41. The large increase in iodine number again was accompanied by a pronounced decrease in hardness (the butter was very soft), notwithstanding the simultaneous decrease in Reichert-Meissl number.

In the case of alfalfa hay, a heavy or exclusive diet invariably produces a very unsatisfactory body and texture of butter (sticky or crumbly). The general trend of fat constants here also lies in the direction of low iodine number, low Reichert-Meissl number and high melting point, as shown by Stout and Wilster,[46] and Hill and Palmer.[47] However, the same investigators, and also Richardson and Abbott,[48] and Hansen and Shaw[49] have found much variation in iodine number, in some cases the defective body resulting from a heavy alfalfa hay diet was accompanied by an increase of the iodine number, while all results appeared to show a consistent decrease in the Reichert-Meissl number.

The addition of silage to the dry hay ration, especially grass or legume silage, usually tends to lessen the hardness and to improve the body of winter butter. This was shown by the

work of Moore,[50] Crasemann and Widmer,[61] and Richardson and Abbott.[48]

In the case of concentrates in the ration, the predominating experimental evidence shows that the iodine value of the fat in the feed ration tends to determine the iodine value of the butter fat and the relative hardness of the butter. The marked influence on the butter fat constants of the addition of corn oil, linseed oil and cottonseed oil, respectively, to the feed ration, is shown by Hunziker et al[31] in Fig. 65.

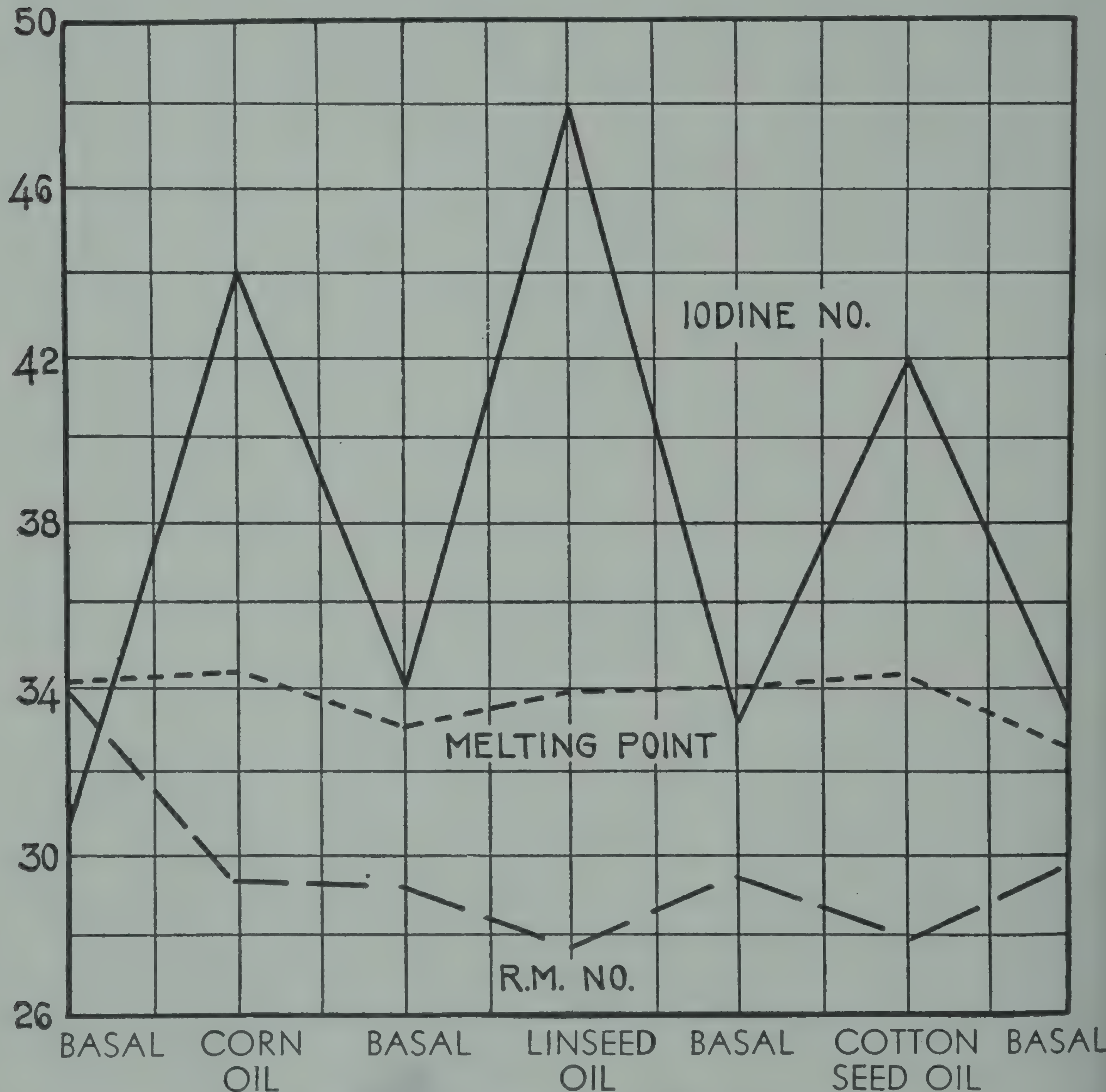


Fig. 65. Effect of oil feeds on butter fat constants

Cottonseed products, when they constitute a considerable portion of the feed ration, lower the iodine number and the Reichert-Meissl number, raise the melting point and yield butter with a peculiarly firm and gummy body. Cottonseed products

contain some stearic acid, which is retained in the hulls. It is this high-melting point fat (stearin) to which is attributed the character of the resulting butter fat.

Underfeeding has a very definite effect on the chemical and physical fat constants. It causes a decline in the Reichert-Meissl number and saponification value, and an increase in the iodine number, as shown by the work of Eckles and Palmer[53] and of Arup.[45] It appears that a low plane of nutrition causes the animal to utilize some of the lower fatty acids (volatile acids) for her own maintenance, thus diminishing the supply of volatile fatty acids available for milk secretion.

In general then, and exceptions, such as may result from certain combinations of feeds in the ration, or from peculiarities of individual cows, reserved, the effect of the various types of feeds on the fat constants and on the body of the butter lies in the following direction:

Feeds That Make Soft Butter.—Feeds rich in vegetable oils, such as germ oil, corn oil, linseed oil, linseed meal, linseed cakes, soybean oil, soybean meal, sunflower cakes, rape cakes, cottonseed oil, glutenfeeds rich in fat (when fed in large quantities), also green forage plants such as green pasture, green clover, green alfalfa, green coarse fodder, and blue grass pasture, tend to increase the iodine number (% olein) and decrease the Reichert-Meissl number (% volatile fatty acids). They may or may not also affect the melting point. Glutenfeeds and pasture grass lower the melting point. The feeds enumerated in this group tend to decrease the hardness of butter, and when they are fed heavily, make soft butter.

Feeds That Have No Pronounced Effect on Body of Butter.—Feeds rich in carbohydrates and sugars, such as beets, sugar beets, mangels, beet tops, molasses, sweet corn fodder, corn silage, Buckwheat middlings, corn meal, bran, tend to increase the percentage of volatile fatty acids and to decrease the percentage of olein. Their effect on the melting point is variable and not pronounced. Their effect on the hardness of the butter is not pronounced. Other feeds that tend to yield butter of normal hardness are corn, oats, glutenmeal with less than 3% fat, grass, soy-bean meal free from oil, dried brewers' grains.

Feeds That Increase Hardness of Butter.—To the feeds that increase the firmness of butter belong hay, timothy hay, alfalfa

hay, cottonseed, cottonseed meal, cottonseed hulls, barley, rye, rye bran, cocoanut cakes. These feeds tend to decrease the percentage of olein.

The cottonseed products when fed in large quantities yield a gummy, hard butter that does not melt readily in the mouth. Alfalfa hay gives butter a sticky, crumbly texture. Alfalfa hay and timothy hay, in combination with beet pulp, yields butter with a low iodine number and abnormal hardness. A ration heavy with alfalfa hay generally decreases the iodine number, although in isolated cases the opposite effect has been observed. In either case, however, the tendency is toward a sticky, crumbly body.

Effect of Size of Fat Globules.—The size of the fat globules contained in the cream has a marked effect on the churnability and on the physical character of the butter. This was experimentally demonstrated by Hunziker, Mills and Spitzer,[31] who separated small-globule cream and large-globule cream from the same milk. The fat globules in the small-globule cream averaged 3.415 microns in diameter; the fat globules in the large-globule cream averaged 4.693 microns in diameter. The churning was done under identical conditions as to temperature and agitation.

The small-globule cream churned with difficulty, requiring over twice as much time to "break," as the large-globule cream. It formed round, hard, smooth granules, which did not pack readily. The body of the butter was abnormally firm, had a short grain and crumbly character. The large-globule cream churned rapidly, formed soft flakes with irregular contour and ragged edges, which packed readily and produced a rather soft butter with a pliable, tough body and a good grain.

The size of the fat globules is determined predominatingly by breed and period of lactation, although it is influenced also by the individuality and physiological condition of the cow. The Channel Island breeds produce fat globules that average approximately twice as large (volume) as the Ayrshires and Holsteins. This assists to explain why the cream from Jersey and Guernsey cows churns more readily and more exhaustively than cream from Holstein and Ayrshire cows, and why the cream from cows early in lactation churns quicker than the cream from "stripper" cows.

The fat globules average largest at the beginning and smallest toward the end of the period of lactation. There is a consid-

erable variation in size of fat globules between individual cows of the same breed. Subjecting the cow to abnormal or unusual conditions that affect her physiological functions, such as abrupt changes in feed, or environmental disturbances such as excitement, irregularity of milking, rough treatment, also sickness, usually causes an abrupt increase in the size of the fat globules, returning to normal as soon as the cause of the disturbance is removed.

Since the majority of the cows in most sections of the country freshen in the spring of the year and are, therefore, in advanced lactation in late fall and early winter, it is probable that the usual tendency of winter butter to show a short grain body with a tendency to crumbliness, is attributable, in part at least, to the small size of the average fat globules contained in winter cream. These facts may further provide at least a partial explanation for occasional churning difficulties experienced in farm buttermaking, in the case of cream produced exclusively from Holsteins and Ayrshires, at a time when the cows approach the end of their period of lactation. In the creamery, the factor of breed is generally of less importance and largely negligible, because the cream supply territory usually embraces a varied mixture of several breeds and grades of cows.

The results of analytical study of the chemical composition of the fat globules overwhelmingly indicates that there is no appreciable nor consistent difference in the values of the fat constants between small and large fat globules. Shaw and Eckles[54] found no appreciable difference in chemical composition of different size fat globules. Hunziker et al[31] reported similar results, the small globules, however, showed a slightly lower Reichert-Meissl value, a fact which was also noted by Eckles and Shaw.[55]

It is conceivable, however, that the small fat globules are less sensitive to and less affected by the concussion of the churning process, and that their "membranes" resist distortion and rupture more readily than is the case with large fat globules. This would tend to retard exposure of free fat, minimize adhesion and clumping, and delay the "breaking" of the emulsion. It would also tend to diminish the proportion of free fat in the butter and react against plasticity of texture, and in favor of a more crumbly character.

Furthermore, the larger surface area of the small globules

suggests more "membrane" substance present. This, together with the lesser disruption of their "membrane" would augment the amount of "membrane" material transferred to the butter, which in turn may result in a modification of the texture of the butter. As explained under the heading "Effect of Viscosity of Cream," the higher protein content of milk and cream from cows late in lactation, coinciding with the period of small average size of fat globules, may also enter into the diminished churnability of such cream.

Effect of Richness of Cream.—Cream with high fat content churns more rapidly than low-fat cream. The greater the concentration of the fat globules in the cream, the closer they are together, the more readily they aggregate, coalesce and form butter granules. The lower the fat content of the cream the greater the volume of intervening serum that keeps the fat globules apart, the slower their rate of aggregation and coalescence, and the longer the time required for butter to form.

The most suitable richness of cream for churning purposes lies within the approximate range of 30 to 35% fat, preferably about 33% fat. Excessively rich cream is objectionable because it tends to stick to the churn, sliding down its sides and subjecting the fat globules to a type of mutilation that leads to a greasy-bodied butter. Such cream also tends to overtax the working capacity of the churn, interfering with efficiency of moisture incorporation and uniformity of composition. Cream of abnormally high fat content is inevitably deficient in serum solids. If standardized to a normal fat content, it should, therefore, be diluted, not with water, but with skim milk, or other milk product that will help to correct this deficiency. Standardization with water interferes with the proper functioning of the cream ripening process, robs the body of the butter of the "mellowing" influence of the protective milk colloids, and tends to give the butter a flat, washed-out flavor and absence of aroma.

Abnormally low-fat cream not only prolongs the churning process, but in the presence of small average size fat globules and low temperature it may cause serious churning difficulties. The prolonged concussion yields very compact, round granules with smooth surfaces, which do not pack readily and produce butter with low moisture content. If cream with abnormally low fat content cannot be conveniently standardized upward to a reasonably normal fat content, it is advisable to reduce the size

of the churning. This will hasten the churning process somewhat, avoiding the necessity of raising the churning temperature to a point that would cause objectionable leakiness. Cream with excessively low fat content is objectionable further, in that it lowers the capacity of vats and churns, makes moisture control in churns with worker rolls difficult, and increases the volume of buttermilk, thereby augmenting the pounds of fat lost. Thin cream also yields to flavor-damaging fermentation more readily than rich cream.

The effect of richness of cream on fat losses was determined by Bird and Derby,[56] who found that the buttermilk tests average lowest with cream of a richness ranging from 25 to 30%. The percentage of total fat lost in the buttermilk, on the other hand, was highest with 20% cream, decreased rapidly as the richness of the cream was increased and was lowest in the case of cream containing 37.5% fat. See also "Fat Losses in Buttermilk" later in this Chapter.

Effect of Viscosity of Cream.—The more viscous the cream the more time is required to complete the churning process. Viscosity is one of the forces that assists in stabilizing the dispersed state of the fat globules and in lending permanency to the fat-in-skim milk emulsion. A viscid condition of the cream diminishes the freedom of movement of the fat globules, it lessens their opportunity of being brought together, it tends to dissipate the effect of the force of concussion on the fat globules in the churn, and to retard coalescence, thereby prolonging the churning process and jeopardizing the exhaustiveness of churning. In the case of extremely viscous cream the delay of butter formation is further aggravated by increased incorporation of air and excessive foaming.

The churning difficulties attributed to increased viscosity of cream from stripper cows are probably further aggravated by the added effect of the small average size of fat globules in such cream, due to advanced lactation, and to the preponderance of high-melting point fat and other chemical changes due to winter feed. In some cases abnormal bacterial fermentations may enter into the reactions that bring about high viscosity and delayed churning. See also Churning Difficulties in later paragraphs.

Effect of Acidity of Cream.—Sour cream churns more rapidly and more exhaustively than sweet cream. The acidity of

the cream affects the churnability and exhaustiveness of churning chiefly to the extent to which it modifies the viscosity of the cream serum, and within certain limits to the extent of its influence on the electric charge on the fat globules, as explained earlier in this chapter. The souring of cream to a point of coagulating or precipitating the casein reduces the viscosity of the cream serum. In this granular, dehydrated condition the casein surrenders its emulsion-stabilizing property, improves the freedom of movement of the fat globules and facilitates their contact. This in turn shortens the churning period and makes for maximum exhaustiveness of churning.

Fundamentally, sweet cream requires more time to churn and churns less exhaustively than sour cream. The danger of high fat losses can be avoided, however, by cooling the sweet cream to a lower temperature. This will prolong the churning period somewhat, but it makes possible practically as complete exhaustiveness of churning as with sour cream. For satisfactory exhaustiveness of churning under normal conditions of operation, sweet cream should be churned at a temperature that will require a churning time of about 50 to 60 minutes. For ripened cream and for sour neutralized cream, a churning time of 30 to 40 minutes is usually sufficient.

The improved exhaustiveness of churning in the case of sour cream is believed to be further due to the decrease in the electric charge on the fat globules, minimizing their electrical repulsion and increasing their ability to come together. It was shown under "Electric Charge on Fat Globules," earlier in this chapter, that within certain limits the electrical potential decreases with increasing acidity.

Effect of Churning Temperature. — The temperature to which the cream is cooled, the time held and the temperature at which it is churned are the controlling factors in the rapidity and exhaustiveness of churning. As explained under "Cooling Cream Preparatory to Churning," in order to insure satisfactory exhaustiveness of churning and the desired firmness of butter, the cream must be cooled to a temperature that will cause at least partial solidification of the butter fat. Proper adjustment of temperature is in fact the most effective means to correct the effect of the multitude of uncontrollable factors that cause wide fluctuations in the character of the butter fat, which influence the firmness of the butter, and the buttermilk test. Proper at-

tention to temperature provides the control that makes for uniformity of churning results.

It is especially at the time of abrupt seasonal changes in the character of the butter fat, when prompt adjustment of the cooling and churning temperature is important. As previously shown, a change from dry winter feed to green pasture increases the proportion of fats with low melting points (soft fats), while a change from pasture to dry feed has the opposite effect.

In most sections of this country, excepting where special feed conditions prevail, a churning temperature of 46 to 48° F. in summer and of 54 to 56° F. in winter, covers the typical seasonal range of temperature that will yield butter of satisfactory firmness and insure exhaustiveness of churning. In the spring of the year, at the time when some of the cows begin to find green pasture, vigilance on the part of the buttermaker is particularly essential, in order to avoid soft, slushy butter, high moisture, and excessive fat losses in the buttermilk. With the first appearance of higher color in some of the cream receipts, the churning temperature needs lowering sufficiently to maintain a normal churning time and thereby avoid the costly defects that would accompany the sudden change to grass cream. The color of the cream and the churning time are dependable signals that tell the observant buttermaker the need of watching his churning temperatures in the spring of the year.

While the above range of seasonal churning temperatures is typical of most sections of the country, they do not apply in some regions because of unusual feed conditions. This is the case in certain sections of the South, for instance, where there is an abundance of cheap cottonseed products, and where cottonseed hulls and cottonseed meal are fed in relatively large quantities. As shown under "Effect of Feed" earlier in this chapter, these feeds yield an abnormally firm, gummy butter, a condition which so far has refused to satisfactorily respond to corrective methods in manufacture. Creameries located in these sections have found it necessary to raise the churning and wash water temperature in order to avoid excessive hardness of butter, difficulties in the incorporation and control of moisture, and a damaging strain on churn workers and churn gears and clutches. In extreme cases it has been found necessary to use churning temperatures as high as 72° F.

As explained under "Effect of Acidity of Cream," sweet

cream must be churned at a lower temperature than sour cream, in order to avoid excessive fat losses. The buttermaker who is accustomed to churning sour, neutralized cream, or ripened sweet cream, usually experiences high buttermilk tests when changing to the churning of sweet cream without lowering the churning temperature.

The relation of churning temperature to original cooling temperature of cream varies largely with the time held between cooling and churning. The time held must usually be adjusted to the economy of the factory routine. This, in turn, varies with volume of cream handled, vat capacity and churn capacity of the creamery. During the flush season some of the cream may have to be churned soon after cooling, to make vat room for more cream, while other lots of cream may have to be held over night in order to avoid prolonging the work day.

For cream held over night, the temperature cooled to is best adjusted to a point that will yield a normal churning temperature on the following morning. Since the temperature change of the cream over night is influenced by the temperature of the atmosphere, summer cream usually must be cooled to considerably below the normal churning temperature, while winter cream may be cooled to a temperature no lower and, under certain conditions, even slightly higher than the normal churning temperature.

Short-held cream (1 to 2 hours) should be cooled several degrees below the normal churning temperature, and cream churned immediately after cooling requires cooling to from about 8 to 15° F., according to season, below normal churning temperature, in order to avoid excessive fat losses in the buttermilk. Even in the presence of these adjustments in the temperature cooled to, there is a general tendency for cream held over night to yield lower buttermilk tests than short-held cream and than cream churned without holding.

Regardless of method of procedure, the accomplishment of a firm body of butter that will stand up well under unfavorable temperature conditions, and of satisfactorily low buttermilk tests, make it essential that at some stage between the pasteurizer and the churn, the cream be cooled to a sufficiently low temperature or held at the cooling temperature long enough, or both, to insure a sufficient degree of fat solidification. The shorter the time of holding, the lower must be the temperature

to which the cream is cooled. Such cream is not appreciably affected by a subsequent slight rise in temperature and can be churned at a sufficiently high churning temperature to churn out in the desired length of time, yield butter of optimum firmness and confine the buttermilk test to normal.

The most dependable guide for the temperature requirements that will accomplish these results is the churning time. This lies within the range of approximately 30 to 60 minutes, with an average of about 45 minutes under usual normal conditions.

Effect of Fullness of Churn.—For maximum agitation and concussion in the operation of the typical creamery churn with revolving drum, the cream must dash from side to side, or from top to bottom. The amount of agitation influences the time required for the churning process, and the fullness of the churn has a marked effect on the amount of agitation to which the cream is subjected.

A churn filled from one-third to one-half full provides sufficient agitation to complete the churning process within the range of time (30 to 60 minutes), that has been found necessary to accomplish maximum exhaustiveness of churning under any given set of conditions.

Overloading the churn decreases the free space for the dashing action of the cream, diminishes concussion, and prolongs the churning period. Crowding the churn with too much cream in an effort to reduce the number of churnings usually proves to be mistaken economy of time and labor. At best it prolongs the churning time, and more often the swelling of the cream due to foam fills the churn completely, preventing further concussion and necessitating the withdrawal of a sufficient amount of cream to make room for the agitation necessary to complete the churning.

The practice of filling the churn more than one-half full is usually accompanied by the use of abnormally high churning temperature, in order to facilitate the formation of the butter granules and to avoid prolongation of the churning period. This is obviously objectionable, as the higher churning temperature increases the fat losses, produces soft granules that do not drain satisfactorily, tends to yield a soft and leaky butter and high moisture.

In the case of rich cream, oversize churnings have the fur-

ther drawback that they tend to overload the working capacity of the churn, making uniform working and satisfactory distribution and incorporation of moisture difficult.

Within reasonable limits a decrease in the size of churnings tends to shorten the churning time. Under conditions that require the use of abnormally low churning temperatures, such as would unduly prolong the churning process, undersize churnings may prove helpful. Excessively small churnings, however, may and usually do lessen agitation and prolong the churning time. Such small churnings have the further disadvantage in that they are more sensitive to extremes in churn room temperature.

In the case of the combined churn and worker excessively small churnings involve moisture control difficulties. The tendency is for the resulting butter to be low in moisture. This problem is eliminated, however, in the case of the rolless churn, which works small churnings as satisfactorily as churnings of normal size. From the standpoint of economy of time and labor, undersize churnings obviously tend to lower the factory operating efficiency.

Uniformity of size of churnings facilitates uniformity of churning time at a given churning temperature, and assists in the control of body and moisture of butter. It is good practice to adopt a standard fullness of churn for all churnings except the inevitable remnant churnings.

Effect of Speed of Churn.—The speed of the churn provides the compelling motive force for the agitation and concussion that causes the fat globules to collide, unite, and form butter granules. The rate of speed, therefore, necessarily influences the degree of agitation and the time required for churning. The optimum speed of the churn is the speed that yields the maximum amount of agitation. It is dependent on the ratio of centrifugal force and gravity force. For maximum agitation the speed of the churn drum must produce enough centrifugal force for the periphery of the revolving drum to carry the cream up to near the top and then permit the gravity force to dash the cream to the bottom.

If the churn revolves too fast, the gravity force is overcome by the centrifugal force, the cream partakes of the centrifugal motion to such an extent that it fails to respond to the gravity force, refusing to break away from the drum periphery, and following the motion of the revolving drum all the way around.

In such case there is relatively little concussion and the churning time is prolonged.

If the churn revolves too slowly, the centrifugal force is insufficient to carry the cream up into the free space, thus eliminating the dashing action, and again there is but little concussion and much time is required to complete the churning process.

The proper speed of the churn, therefore, lies within a range of number of revolutions per minute that is slightly below the speed at which the centrifugal force is sufficient to overcome the force of gravity. Since the linear speed (rim speed) of a drum for a given number of revolutions varies directly with its diameter, an increase in the diameter of the churn drum decreases the number of revolutions required to secure the desired centrifugal force. Directions for the proper number of revolutions per minute are usually supplied by the churn manufacturer.

Effect of Design of Churn.—The intensity of agitation and concussion of the cream is influenced to a considerable extent by the internal arrangement of the churn barrel. In a completely hollow churn barrel it would be difficult for the revolving drum to lift the cream to the necessary height for proper concussion. Churns are, therefore, equipped with shelves installed close to and parallel with the drum periphery. These shelves raise the cream with each drum revolution to the proper height and permit it to dash away from the periphery. For sanitary reasons these shelves should be set away from the periphery sufficiently (about 1½ inches) to permit ready cleaning between shelf and staves.

In some churn drums several sets of worker rolls take the place of the shelves. In such case the worker rolls should be placed as far as possible from the drum center and in such a position that they perform the duty of shelves during the churning process.

THE CHURNING OPERATION

Preparing the Churn for the Cream.—Before it is ready for the cream, the churn should be thoroughly chilled with clean, cold water, using about 50 gallons of cold water and revolving the churn about 15 minutes with this rinse. For additional protection against bacterial contamination, the cold rinse is preceded

by a rinse with boiling hot water, or the water for the cold rinse is chlorinated. For details of efficient churn treatment before and after use, including also treatment of new churns and of sticky churns, see Chapter IV, under "Sanitary Care of the Churn."

Straining the Cream Into the Churn.—The efficiently sterilized and properly chilled churn is now ready for the cream. The cream should be strained into the churn. A strainer with perforations or meshes from 1/16 to 3/64 inch in diameter is suitable for this purpose. Finer perforations clog the strainer too readily.

The churn strainer will not and should not be expected to remove extraneous matter of microscopic particle size from the cream at churning temperature. Removal of such fine foreign material must be done earlier in the routine of manufacture, when the cream is sufficiently warm and fluid to pass through a much finer strainer.

The purpose of straining the cream at the churn is to break up clots or lumps, and to remove the coarser type of chance objects that may accidentally have gotten into the cream after pasteurization and cooling, such as loose bristles from worn brushes, metal particles from disintegrating chore balls, glass from chipped thermometers, pipettes or graduates, pieces of can seal wires that escaped through and were cut up in cream pumps, flies and other insects.

Obviously such objects should be kept out of the cream in the first place, and, with proper attention in operation, the possibility of their presence in the cream is remote. Yet, accidents of this nature do occasionally occur, in spite of all reasonable precautions, and the systematic use of a properly constructed and efficiently functioning churn strainer provides the most effective means of keeping such chance objects out of the butter.

The churn strainer should be of such construction that all the cream readily and actually passes through without undue clogging that retards the cream flow, or causes some of the cream to flow over the top of the strainer and, therefore, miss the straining action.

In plants that fill their churns by gravity, as is generally the case where the cream vats are located on an elevated platform, the conventional, ready-made basket strainer that fits into the churn door frame is the most practical type of strainer. Where the cream is pumped into the churn, however, the basket

strainer is not suitable, because of its tendency of filling up faster than its perforations or meshes can discharge the cream. This causes objectionable splashing and overflowing.

For pumping the cream into the churn, a two-inch perforated metal tube about 21 inches long, with screw cap at the far end for ready removal for cleaning, and with the intake end soldered to a piece of 2-inch pipe of suitable length and equipped with a union for connection with the threaded end of the downspout of the cream supply pipe located over the churns, has been found highly suitable for the purpose. A splash baffle, about 10 inches in diameter, and soldered to the strainer tube at an elevation just slightly below the churn door frame, prevents the cream from splashing out of the churn.

The churn strainer should be thoroughly washed, rinsed and steamed after the day's use and kept in a suitable, clean place where it is protected from contamination and from mechanical damage, while not in use. Before use it should be efficiently steamed, and between churnings it should be rinsed, kept off the floor and steamed again before the next use.

When making butter on a small scale, such as in farm buttermaking, the use of a dipper strainer provides a convenient way of straining the cream into the churn.

Purity of Water Used for Rinsing Down Cream Vat.—The water that is used for rinsing the remnants of cream out of the vat into the churn enters into the composition of the butter. If it contains quality-damaging impurities it will contaminate the butter. It is just as necessary for this water to be pure as for the water used for washing the butter and the water that is added to the butter in moisture control.

Unless the general water supply of the creamery is of known safe purity, it is wisdom to give the water used for flushing out the cream vat the same treatment, or derive it from the same source, as the water used for washing the butter. See Chapters III and XVI on "Butter Wash Water."

ADDITION OF BUTTER COLOR

The market demands that butter be uniform in color. The natural color of butter is that which is naturally yielded by cows feeding upon green pasture. This color is of a bright golden yellow. During the flush of the milk producing season

the great majority of the cows are on green pasture, therefore the great bulk of butter has this golden yellow color as a natural ingredient. Towards fall when the pastures begin to dry up, the natural color of the butter becomes lighter and in winter, when the cows are on dry feed, butter is only faintly yellow, the exact shade of color varying considerably with kind of feed, breed of cows, and period of lactation. The Channel Island breeds produce a more highly yellow butter than the Holsteins and Ayrshires, and at the beginning of the period of lactation the cream and butter have a deeper shade of yellow than after the cows have been in milk for some months. All green feeds and yellow roots intensify the yellow color of butter, while most dry roughage, grains and mill by-products tend to diminish the yellow color of milk and dairy products. (See also Chapter XXIII under "Defects in the Color of Butter.")

In order to maintain uniformity of color throughout the year, butter is artificially colored when the color naturally present is insufficient to satisfy the trade. For this purpose a variety of butter colors is used. A suitable butter color must be free from ingredients injurious to the health of the consumer. It must be free from undesirable odors and flavors which would impair the quality and market value of the butter. It should have such strength of coloring principle, that only a very small quantity need be added, and it should have such permanency of emulsion as to prevent settling out of the coloring principle upon standing. The butter color must be oil-soluble in order to color butter fat. The vehicle carrying the coloring principle is a neutral oil such as corn oil or cottonseed oil. The coloring principle is either of vegetable or of mineral origin.

Vegetable Butter Colors.—This class of butter color derives its coloring principle from plants. While extracts from various plants may serve as butter colors, the bulk of the vegetable butter color of commerce today is made from the coloring substance extracted from the seed of the annatto plant (Bixa oreltana), which is dissolved in a neutral oil.

The extract of vegetable butter color is made by boiling the annatto seed in the oil for several hours. During the latter period of the process the heat is raised to a high temperature, about 240° F., for the purpose of effecting a permanent solution of the annatto coloring principle in the oil. The mixture is then

filtered through heavy canvas, either by gravity or under pressure. The filtered oil constitutes the butter color of commerce. It is perfectly clear to the eye, but under magnification shows the presence of very fine particles of suspended matter.

Mineral Butter Colors.—The coloring principle of mineral butter colors is derived from harmless oil-soluble coal tar dyes. The coal tar dyes certified by the U. S. Department of Agriculture, Bureau of Chemistry, are "Yellow A B (Benzeneazo-β-naphthylamine)" and "Yellow O B (Ortho-Tolueneazo-β-naphthylamine)."

These oil-soluble coal tar dyes, which have been approved for use by the U. S. Government, are mixed with the neutral oil, boiled, and filtered in a similar manner as in the manufacture of vegetable butter colors.

The mineral butter colors now on the market, which have been legalized, have the advantage of greater concentration of the coloring principle. Less of the butter color is needed to produce a given shade of yellow than is the case with vegetable colors. The emulsion of mineral butter color in oil has proved more permanent and the danger of unevenness in strength has thereby been minimized. In case of vegetable butter color there is always more or less of a tendency for the oil to drop its coloring principle upon long standing. This jeopardizes the uniformity of its strength.

Keeping Quality of Butter Color.—Low temperature, abrupt changes in temperature, exposure to air, and agitation, tend to accelerate the precipitation of butter color. If made from a high grade neutral oil and sound coloring principle, butter color does not deteriorate when kept at room temperature, unless held over from one season to another.

The drums, cans or other containers of butter color should, therefore, be stored in a place where the temperature is fairly uniform, and preferably at room temperature, and their contents should be protected against excessive agitation and exposure to air. The practice of pumping the butter color out of the drum when it is needed, tends to incorporate considerable air in it. This excessive and repeated agitation invites precipitation. It is preferable to lay the drum on a sleeper and draw the butter color through a spigot.

Amount of Butter Color to Add.—The shade of yellow de-

sired in butter varies with market requirements. American markets, as a whole, demand a higher shade of yellow than European markets, although there is a growing preference for a lighter color than formerly, in American markets. The southern markets require a deeper yellow than the northern and eastern markets, where a straw color is preferred. The Jewish trade demands uncolored butter.

The amount of artificial butter color that must be added, then, varies greatly under these diverse conditions and it may range from none to about 4 ounces for every 100 pounds of fat in the churn. One ounce of butter color for every hundred pounds of butter fat in the churn is a fair average amount for winter cream. In order to maintain a uniform shade of yellow in the butter, changes in the amount of butter color added to compensate for seasonal changes in the natural color, should be made very gradual, increasing or decreasing the amount by not more than one quarter ounce at a time.

Manner of Adding Butter Color.—The butter color is preferably added to the cream at the churn. If this has not been done, it may be added to and mixed with the salt just before working. It is then worked into the butter and distributed with the salt. This practice cannot be recommended for general use, owing to the difficulty of working the butter sufficiently to effect a complete and uniform distribution of the color without overworking. It should be resorted to only in emergencies.

Yellow Color the Natural Trade Mark of Butter.—The yellow color is the legitimate trade mark of genuine butter, wisely provided by nature. This trade mark automatically distinguishes butter, in appearance to the eye, from substitutes and imitation products. Upon this trade mark—the yellow color—the butter manufacturer depends largely for protection against unlawful competition from butter substitutes. Upon this same trade mark the consumer must rely for protection against receiving imitation products when he asks for, buys, and pays for butter.

OPERATING THE CHURN

Gas in the Churn.—During the first 5 to 10 minutes of churning considerable pressure develops in the revolving churn. This appears to be due to the liberation of air and gases from the

cream. This pressure tends to slightly minimize agitation, and in case the churn doors fail to close tightly, it causes leakage of cream. It is customary to open the churn vent once or twice during the early minutes of churning, to permit these gases to escape.

Rise of Temperature During Churning.—During the churning process there is invariably a rise in temperature of several degrees. The temperature of the butter and buttermilk usually is from about 2 to 5° F. higher than the original churning temperature of the cream when the churn is started.

This rise in temperature is chiefly due to the friction produced in the churn by the churning agitation and concussion. The tendency, therefore, is for the rise in temperature to increase with the prolongation of the churning period. This was demonstrated by Hunziker, Cordes and Nissen, as shown in Table 31, who obtained similar temperature increases also by churning water.

Table 31.—Rise of Temperature During Churning

Churn Lot	Cream				Temperature of			
	Amount	Fat	Time Held at Churning Temperature	Churning Time	Churn-Room	Cream in Churn*	Butter and Buttermilk	Rise in Temperature During Churning
No.	Lbs.	%	Hours	Min.	°F.	°F.	°F.	°F.
1	2250	35	16	40	52.3-53.3	52.9	55.0	2.1
2	2100	31	16	65	52.5-54.1	52.5	55.7	3.2
3	2150	27	16	70	51.4-52.9	51.4	55.7	4.3
4	2400	29	16	50	53.4-54.3	54.0	57.2	3.2
5	2250	37	16	35	66	54.0	56.8	2.8
6	2250	37	2	45	67 -68	53.1	56.8	3.7
7	2100	33	2	40	56	50.2	52.7	2.5

*The temperature of the cream was taken after giving the churn 10 revolutions.

Other factors that may, under certain combinations of conditions, contribute toward the rise in temperature during churning are absorption of heat from the churn proper, and absorption of latent heat released by progressive crystallization of some of the fat that is still present in liquid form.

In the case of the wooden churn, absorption of enough heat from a warm churn room atmosphere, to materially raise the temperature in the churn during a normal churning period is

improbable, and the possible temperature rise negligible. Lack of proper chilling of a steamed wooden churn, however, is conducive to a noticeable rise in temperature during churning. A similar tendency may be expected from a metal churn operated in a warm churn room.

In cream cooled rapidly and churned shortly after cooling, the latent heat released by crystallization of at least part of the fat that is still present in liquid form, may cause a very definite rise in temperature during the churning. In such case the temperature rise is further accentuated by the fact that butter fat is a slow conductor of heat. In quick cooling and immediate churning, therefore, the temperature of the butter fat itself may be considerably higher than that registered by the cream. Under average, normal conditions of operation, however, the release of heat by the butter fat in the churn appears to be a minor factor, as shown by the fact that the churning of water is accompanied by a similar rise of temperature in the churn as is the churning of cream.

When to Stop the Churn.—Under normal conditions, the churning process is completed when the butter granules have reached the size of crushed corn kernels. When the butter first breaks and the spy glasses become clear, the butter granules are as yet very small, the buttermilk still has a rich, creamy, opaque color. From this point on, the formation of additional butter granules, their coalescence into larger ones and the completion of churning usually take place rapidly. When the butter granules are sufficiently large (a little larger than wheat grains and preferably the size of crushed corn kernels), even the smallest granules are of sufficient size to prevent their escape through the buttermilk strainer. At this point the buttermilk has lost its creamy consistency and opaqueness. It now is thin, bluish and watery in appearance, indicating that it has surrendered all the fat that the churning action is capable in removing.

Underchurning, or stopping the churn and removing the buttermilk when the butter granules are still very small (of the size of small wheat kernels or smaller), causes excessive loss of fat. The loss in such case may be minimized somewhat by leaving the churning undisturbed for a while before the buttermilk is removed. This facilitates the rise of the small butter granules still contained in the buttermilk to the surface, where they may attach themselves to the butter, but even this

precaution is inadequate to prevent high buttermilk tests when stopping the churn before the butter granules have reached the proper size.

Overchurning, such as results in the formation of abnormally large granules and lumps, is objectionable because of excessive incorporation of buttermilk, which cannot be removed by subsequent washing. In the case of cream of poor quality, overchurning is especially objectionable, because the buttermilk so incorporated tends to give the butter an unclean, coarse and rank flavor, and to hasten changes in the butter that are detrimental to its keeping quality. The most common cause of overchurning has to do with conditions that yield abnormally soft butter granules. Such granules coalesce readily and quickly. It is difficult to stop the churn before the butter is overchurned, when the cream has not been cooled sufficiently to make the butter come reasonably firm.

CHURNING DIFFICULTIES

Occasionally the cream in the churn is of such a nature that the butter granules are exceptionally slow in forming and in gathering. Because these churning difficulties have to do largely with the peculiar character of the cream from certain cows, they are more apt to occur in farm buttermaking, where the source of the cream is confined to a single herd and often to a few cows, than in the creamery where the churnings represent a mixture of cream from numerous herds.

Usual Causes of Churning Difficulties.—Instances of churning difficulties causing undue prolongation of the churning period, and in extreme cases rendering the formation of butter impossible, are usually traceable to combinations of conditions in which excessive hardness of fat, small size fat globules, thinness of cream, high protein content of cream and lipolysis are primary or contributing factors.

Excessive Hardness of Butter Fat, such as is characteristic of winter cream from cows fed on dry feeds, or on certain combinations of dry feeds, prolongs the churning time because it diminishes the ability of the fat globules to coalesce when they are brought together by the churning agitation.

Small fat globules, such as predominate in the cream from cows in advanced lactation are slow to form butter granules,

because they represent a larger ratio of protective "membrane" material to fat, and because they are more resistant to distortion and to the "membrane"-rupturing action of the churning concussion. They, therefore, coalesce and clump less readily than do large fat globules, such as predominate in cream from cows in earlier lactation.

Abnormally thin cream, such as cream testing less than 25% fat, prolongs the churning process, because it increases the ratio of protein to fat in cream, and augments the proportion of intervening serum that keeps the fat globules apart and that lessens the force of their impact, decreasing agglutination and retarding clumping.

High protein content, such as is characteristic of cream from cows in advanced lactation and from cows which have not been with calf for a long time, impedes butter formation because of increased viscosity that minimizes the force of concussion.

High lipase content, such as often occurs in "stripper" cream, makes for excessive foaming and retards butter formation, because it encourages lipolysis that may result in the formation of soap from fatty acids liberated by lipase action.

Any one of the above factors is capable of retarding the churning process. In the majority of serious churning difficulties, however, a combination of several of these factors is usually involved. Winter feed and advanced lactation are generally the background of the trouble, and, since their occurrences coincide, the churning difficulty is usually traceable to their combined effect. And again, since they have to do largely with winter cream, it is in late fall and winter when they are most apt to assail the buttermaker.

Surplus Cream From Milk Plants.—While, as previously stated, serious churning difficulties are predominatingly a problem of farm buttermaking, the creamery is not altogether immune to them. It is especially in connection with the churning of special cream, such as surplus cream that may be received by the creamery from condenseries, ice cream factories and market milk plants, that churning difficulties may arise.

In such case the trouble is usually found due to the treatment which the surplus milk or cream may have received in those factories. Thus any treatment that changes the physical character and increases the permanency of the emulsion, such

as heating the milk before separation with direct steam (live steam) to near the boiling point, or homogenizing all or part of the milk or cream, has been found at least contributing causes of the difficulty. The fact that cream from these sources is usually sweet and not infrequently of abnormally low fat content, further aggravates the difficulty. Some of this type of cream may have a noticeable rancid odor, suggesting that it has been subjected to conditions that favor lipolysis, causing excessive viscosity and profuse foaming.

Means to Prevent or Overcome Churning Difficulties.—In most cases, churning difficulties will yield wholely to, or are minimized by proper handling of the cream in the factory. A reasonably rich cream (about 30%), ripened to approximately .25% acid, churned at a temperature that will yield normally firm butter, in a churn from one-third to a little less than one-half full, seldom refuses to churn out in a normal churning period (30 to 60 minutes).

When cream foams and swells to the point of completely filling the churn, however, continuance of the churning operation becomes useless, as all agitation ceases, until the foam has subsided.

If the frothing is due to overloading the churn, the quickest way to complete the churning is to remove a sufficient amount of the cream from the churn to make possible the resumption of vigorous agitation. If the swelling and retardation of butter formation are due to too cold cream or to abnormal viscosity due to other causes, the addition of a small amount of hot water usually helps to overcome the difficulty. The hot water should be used sparingly to avoid excessive dilution of the cream, that would further retard the churning action.

The addition of dry salt likewise is helpful. The salt has the effect of precipitating or "salting out" the curd, partially dehydrating the casein and reducing the viscosity of the cream. Not infrequently churning difficulties not due to an overloaded churn are overcome, and the breaking point hastened, by turning the hot water hose on the outside of the revolving churn. The resulting slight warming of the churn barrel assists the cream in breaking away from the wood, making possible the resumption of normal concussion.

Overloading the churn is one of the most common causes

of churning difficulties, due to the natural tendency on the part of the buttermaker to reduce the number of churnings to the minimum. Filling the churn more than half full invariably prolongs the churning time, and in the case of cream of poor churnability it may prevent butter formation altogether.

In case of churning difficulties due to the particular character of the cream, it is helpful to make smaller churnings than normal, filling the churn not more than one-third full.

The effect of overloading the churn on the time required for completion of the churning is convincingly shown below, by the experiments of Combs and Coulter,[57] using a standard type factory churn of 1200 lbs. listed working capacity, and churning 30% cream that had been cooled to 45° F. and held over night. The maximum normal load for such a churn is 2,500 lbs. of cream.

Churn Load	Cream in Churn Lbs.	Temperature Churned °F.	Churning Time Minutes
Overloaded	2800	52	270
Normal Load	2340	51	50
Overloaded	2816	53	360
Normal Load	2310	53	52
Overloaded	3000	53	540
Normal Load	2350	48	65

Change in feed ration of the cows that are on dry winter feed assists in improving the churnability of the cream. Where the buttermaker has control over the feeding of the cows, as is usually the case in farm buttermaking, considerable improvement in the churnability of slow-churning cream can often be accomplished by the addition to the feed ration of some succulent feed, such as roots or silage, or of concentrates rich in vegetable oil, such as linseed meal.

The succulence increases the milk flow and tends to reduce the viscosity. Grains or other concentrates rich in oil increase the percent olein, causing the butter fat to be softer and facilitating coalescence of the fat globules. In the case of abnormal character of "stripper" cream. however, the churning difficulty generally refuses to respond to a change in feed. With the freshening of the cows the milk usually returns to normal.

Proper handling of "stripper" cream on the farm shortens the churning time. Churning difficulties due to lipolytic action

in cream from "stripper" cows are greatly minimized or largely prevented, by pasteurizing the milk as soon as drawn or the cream as soon as separated, and by separating the cream while the fat globules are still in a liquid state, i. e., before the milk has been cooled, as suggested by Krukovsky and Sharp.[58]

FAT LOSSES IN BUTTERMILK

The fat lost in churning constitutes the largest factor of the total fat loss in the manufacture of butter in creameries receiving cream. The fat contained in the buttermilk is derived from three principal sources, namely fat globules that are too small to churn out, fat globules entrained in the curd particles, and fat in the form of butter granules that are sufficiently small to pass through the buttermilk strainer.

Distribution of the Fat in the Buttermilk.—Part of the fat of the buttermilk is dispersed in the serum portion and the remainder is contained in the curd portion. The ratio of fat in serum to fat in curd varies widely with diverse factors in manufacture, such as original acidity of cream, acidity of cream when pasteurized, kind of neutralizer, manner of neutralization and temperature of pasteurization. In creameries receiving sour cream, the general tendency is for the curd fraction to contain a larger portion of the total fat of the buttermilk than the serum fraction. High acidity at the time of pasteurization, faulty neutralization and high temperature of pasteurization of sour, and sour-neutralized cream, tend to increase the fat content of the curd fraction. Lime neutralizer likewise increases the fat content of the curd, while soda neutralizer (particularly caustic soda) tends to decrease it.

Hunziker and Cordes,[59] who allowed buttermilk from 17 churnings of sour, neutralized, flash pasteurized cream to separate by gravity, and, with the help of coagulants, found the serum fraction in all cases to contain less of the total fat content of the buttermilk than the curd fraction. The fat in the serum ranged from mere traces to 45%, averaging 29.6% of the total fat in the buttermilk. The clearer the serum, i. e., the more complete its separation from the curd, the lower was the fat content of the serum.

Similar results were reported by Ruehe and Stiritz,[60] who separated buttermilk by centrifuging. They found the curd frac-

tion from sour, unneutralized pasteurized cream to contain 73.7% of fat of the buttermilk. Lime, and lime and soda neutralization also yielded a larger portion of the buttermilk fat in the curd fraction, while with caustic soda neutralizer the whey fraction contained 71.8% of the buttermilk fat, obviously due to the solvent action of this alkali on the curd. Their addition of hydrochloric acid, or salt, or both, to the cream before churning, for the purpose of reducing the buttermilk test, likewise materially decreased the proportion of fat contained in the curd fraction.

Factors That Influence the Fat Losses in the Buttermilk.—The known factors that affect the buttermilk test and the mechanism of their action, were discussed in detail under their proper subjects. They are briefly summarized below:

1. **Effect of Season on Buttermilk Test.**—The general trend is for higher fat losses in summer than in winter. Lowering the cooling temperature of the cream sufficiently to compensate for the softer summer fat assists in exhaustive churning of summer cream.

2. **Effect of Neutralization on Buttermilk Test.**—Proper neutralization of sour cream before pasteurization prevents excessive fat losses. Warm the cream to 85-90° F. After addition of the properly diluted neutralizer continue agitation for 10 to 15 minutes before starting to pasteurize. The early clogging of the cream strainer is usually a definite indication of improper or incomplete neutralization that is associated with excessive fat losses. For details see Chapter X under "Objects of Neutralization."

3. **Effect of Temperature and Method of Pasteurization on Buttermilk Test.**—High-temperature pasteurization tends to cause higher fat losses than low-temperature pasteurization. This is especially characteristic of sour cream and sour neutralized cream. Proper neutralization, however, assists in minimizing fat losses.

Pasteurization by the steam injection method yields greater fat losses than standard pasteurization in which the cream is heated by passing over metal heating surfaces. These results apply to both sweet cream and sour neutralized cream. For details see Chapter XI on "Pasteurization."

4. Effect of Treatment for Deodorizing Cream on Buttermilk Test.—Cream deodorization by steam injection and vacuum treatment increases the fat losses from churnings of both sweet and sour neutralized cream. For details see Chapter XII.

5. Effect of Cooling Temperature of Cream and Time Held on Buttermilk Test.—The temperature cooled to and churned at, and the time held before churning are important fundamental factors that control the buttermilk test. When butter comes abnormally fast and is soft, the buttermilk test is invariably high. This is usually due to insufficient cooling of the cream or not holding it long enough at the cooling temperature, or both.

6. Effect of Size of Butter Granules on Buttermilk Test.—Stopping the churn when the butter granules have reached a size intermediate between wheat kernels and crushed corn kernels generally coincides with approximate point of maximum exhaustiveness of churning under average normal conditions.

7. Effect of Overloading the Churn on Buttermilk Test.—Overloading of the churn, in itself, is not known to noticeably affect the exhaustiveness of churning. Its principal objection is that it prolongs the churning time. However, in most cases of an overloaded churn, the buttermilk test is high. This is due to the fact that the oversize churning is usually accompanied by high churning temperature, in order to make the butter come within a reasonable time.

8. Effect of Churning Acidity on Buttermilk Test.—It has been the general experience in commercial butter manufacture that ripened cream and sour neutralized cream yield more exhaustive churning than sweet cream. The experimental results of Bird[61] suggest that the slight souring of sweet cream of moderate richness (about 30% fat) tends in the direction of slightly lowering the buttermilk test, while ripening to around 0.6% acid, such as is practiced in Denmark and other countries of Continental Europe, decreases the buttermilk test very definitely.

In order to accomplish normal exhaustiveness of churning for sweet cream, such cream should be cooled to a sufficiently lower temperature to extend the churning period to 60 to 70 minutes.

9. High-Fat Cream Yields Higher Buttermilk Tests Than Low-Fat Cream.—The work of Bird and Derby[56] has clearly demonstrated that cream within a fat range of 25 to 30% yields the lowest buttermilk tests from the standpoint of richness of cream.

Bird and Derby further correctly point out that, while the buttermilk test increases with an increase in the fat content of the cream, the proportion of fat lost is actually less, reducing the percent fat lost of the total fat churned.

Determination of Percentage Fat Loss of Total Fat Churned.—The importance of accurate knowledge of the total fat lost in churning has been recognized by the industry from the very beginning and numerous methods of varying dependability have been developed and used in efforts to check the actual churn losses. One of the hindrances to these efforts has been the impracticability of an accurate determination of the volume or weight of the buttermilk.

Bouska[62] was one of the first to publicly propose a simple procedure for this purpose, which is as follows: Deduct the pounds of butter made from the pounds of cream churned. The difference is called the buttermilk. Determine the pounds of fat in the buttermilk on the basis of this volume and the buttermilk test. Divide the pounds of fat in the buttermilk by the pounds of fat churned. The quotient represents the percentage fat lost of the total fat churned. This method, then, resolves itself into the following simple formula.

$$\%\text{ total fat loss} = \frac{(\text{Lbs. cream} - \text{lbs. butter}) \times \text{buttermilk test}}{\text{Lbs. fat churned}}$$

Example: 2,000 lbs. of 30% cream used, 735 lbs. butter made. Buttermilk tests .6%. What is the percentage of the total fat lost?

Answer:

$$\%\text{ total fat lost} = \frac{(2{,}000 - 735) \times .6}{600} = 1.265\%$$

In the above example the pounds of butter made (735 lbs.) were calculated on the basis of 80.5% fat in the butter and of making allowance for the .6% fat lost in the buttermilk. These calculations yield a churn overrun of approximately 22.5%, which appears normal.

A similar formula is suggested by Bird and Derby,[56] their

calculations of pounds of buttermilk are based on a fixed overrun value instead of the actual pounds of butter made. They assume that the amount of buttermilk retained in the granular butter before washing is equivalent to a 20% overrun. Analyses in the study of the moisture content of butter at different stages in manufacture by the author suggest that a 20% overrun represents a fairly close approximation of the buttermilk "tied up" in the unwashed butter granules of average normal firmness. Their formula is as follows:

$$\% \text{ total fat lost} = \frac{[100 - (1.2 \times \text{cream test})] \times \text{buttermilk test}}{\text{Cream test}}$$

Using the same values of pounds and test of cream and of test of buttermilk as in Bouska's formula, Bird and Derby's formula yields the following total fat lost:

$$\frac{[100 - (1.2 \times 30)] \times .6}{30} = 1.28\% \text{ total fat lost}$$

As may be seen, the results of the two formula check reasonably closely. The cause of the slight difference of 0.015% lies in the difference in overrun values used.

MERITS OF BUTTERMILK TESTS

If the testing of the buttermilk is to fulfill its intended purpose of enhancing the factory operating efficiency, the method of testing used must provide a fat test of buttermilk that is representative of and comparable with the fat test of the cream. In addition, the test must be sufficiently sensitive to be suitable as a basis for determining the churning efficiency, it must be sufficiently dependable to yield duplicates that check, it must be confined to simple and reasonably inexpensive equipment, and it must be simple and rapid to operate.

Buttermilk Contains Lipins.—True butter fat, similarly as other fats, is composed only of glycerin and fatty acid. The butter fat globules in addition to true butter fat, contain a very thin surface layer of complex fatty materials consisting chiefly of lecithin—phosphorus complexes and to a lesser extent of sterols, such as cholesterol. These fatty compounds that are not true butter fat, are generally known as lipins. When milk is skimmed they follow the fat globules and reappear mostly in the cream. The lipins remain with the fat globules until the globule membrane material becomes wholely or partially rup-

tured, due to the concussion in churning. When the globules unite to form butter granules, a considerable portion of the lipins breaks away from the fat globules and is carried into the buttermilk, causing the buttermilk to contain a relatively large part of the lipins originally contained in the milk and cream.

Readings of Babcock Test of Milk and Cream Include Lipin Material.—The lipins are soluble in ether. Determinations of fat by ether extraction methods, such as the Roese-Gottlieb method and the Mojonnier method, therefore, embrace the lipins as well as the true fat. The reading of the fat column in the Babcock test of milk and cream has been so adjusted as to check with the Roese-Gottlieb method. The Babcock test of milk and cream, therefore, gives the total of the true fat and the lipins present. Hence, the creamery that buys milk and cream on the basis of the Babcock test pays for both, true fat and lipins.

In order for the buttermilk test to be comparable to the fat test of milk and cream it follows that it, too, should record the total of true fat and lipins. However, only a very small portion of the true fat contained in the cream passes into the buttermilk, while the greater part of the lipins of the cream becomes a constituent of the buttermilk. The ratio of lipins to true fat in the buttermilk, therefore, is relatively large, amounting to a little less than .25% of the total fat contained in the buttermilk as determined by the ether extraction method.

Since it is neither possible, nor desirable (because of the quality-jeopardizing effect of lecithin) to recover the lipins in the butter by improved churning efficiency, buttermilk tests that include the lipin content will show fat losses in excess of the true fat. However, since milk and cream also must be and are tested by methods that include the lipins, such buttermilk values appear consistent and desirable, in order to avoid misleading values for mechanical losses.

Available Factory Methods for Testing Buttermilk.—The methods used for testing buttermilk in the commercial creamery, particularly on the American continents, in Australia, and New Zealand, are the Babcock test, the American Association Test, the Minnesota Test and the Mojonnier Test.

The relative merits of these tests have been the subject of study by numerous investigators. The recent extensive work of

Bird, Breazeale and Sands,[63] has contributed much to our present knowledge. They give the following average percentages of tests made in duplicate on 25 samples of buttermilk as follows:

Babcock test	0.232%
Minnesota test	0.513%
Butyl alcohol test (American Association test)	0.652%
Mojonnier test	0.719%

The bulk of the literature on checking the results of the Babcock test of cream against the Mojonnier test, while showing minor deviations in either direction, indicates close agreement between the two methods. This fact suggests that the Mojonnier test of buttermilk should yield fat loss figures that are comparable to the fat purchased in the cream as determined by the Babcock test.

It is obvious from the buttermilk values reported by Bird and co-workers for the four different methods of testing, that these comparisons eliminate the Babcock test of buttermilk. This test is unsuitable. Its fat loss values are too small to accurately show variations in the fat content of buttermilk. The difference between the Babcock test and the Mojonnier was found to be due largely to the extremely small fat particles which refuse to be centrifuged out of the rather viscous sulphuric acid solution into the neck of the test bottle, and to a lesser extent to the absence in the fat column of the Babcock test of lipins. The Babcock method is unsuitable for testing buttermilk also because of the irregularity of its results and the hopelessly wide variations between duplicates that persist in occurring in the hands of the average operator in the creamery.

The Mojonnier test likewise fails to meet some of the essential requirements of a suitable creamery test. While accurate and dependable in showing the fat and lipin content of the buttermilk, the cost of equipment and time and skill required for its operation eliminate it from consideration for use under conditions that prevail in creameries of average volume, and limit its use to factories of large volume only.

This leaves the choice between the Minnesota and the American Association tests. Either method provides satisfactory buttermilk tests, requires no costly additional equipment, and is sufficiently simple to operate to be suitable for use in any creamery. According to the findings of Bird and co-workers,

these two tests are practically equivalent relative to the percentages of the materials that are read as fat, that are either ether soluble or water soluble. Likewise, they both yield clear and readily readable tests, their duplicates check convincingly well and their readings vary consistently with the fat content of the buttermilk.

On the basis of the close check of the Mojonnier test with the Babcock test for cream, it would appear that the American Association test, showing the closer agreement with the buttermilk values given by the Mojonnier test, gives a somewhat more representative test for buttermilk than does the Minnesota test. Likewise, the American Association test is somewhat simpler of operation, as it requires no preliminary heating in a water bath. Directions for this test are given in Chapter XXV on "Factory Tests."

Daily Tests of Buttermilk Are Essential.—Essentially, the choice of test is of minor importance, provided that one and the same test is used for all comparisons of fat loss in the buttermilk. In addition, the buttermilk test is indispensable for determining the percentage fat loss of the total fat churned, which is the real and final answer to the important question of churning efficiency. Since the richness of cream, which is the dominating factor in the percentage of total fat lost, is usually fairly uniform from day to day, the daily buttermilk test alone provides the buttermaker with tangible information as to daily variations in churning efficiency.

Accuracy of Buttermilk Samples.—The fat content of the buttermilk from one and the same churning appears to be essentially the same for all samples, regardless of the time during the draining of the buttermilk when the sample is taken. The results of tests made by Hunziker of the first, middle and last portions of buttermilk pumped from the churn are recorded in Table 33.

The above results are in general agreement with the findings of Ruehe and Stiritz,[60] who compared samples taken at the start and end of the draining. The maximum variation was 0.018%, the minimum 0.004% and the average 0.009%. They concluded that a buttermilk sample taken at any time during draining will be representative, provided that no fat granules get into the buttermilk.

Table 33.—Tests of Buttermilk Samples Taken from First, Middle and Last Portions of Buttermilk Pumped from Churn (American Association Test)

Churn Lot Number	Buttermilk Tests			Maximum Variation	Variation Between First and Last Portion
	First Portion	Middle Portion	Last Portion		
	Percent	Percent	Percent	Percent	
413	0.54	0.55	0.53	0.02	0.01
414	0.55	0.56	0.54	0.02	0.01
415	0.56	0.56	0.58	0.02	0.02
416	0.56	0.58	0.56	0.02	0.00
417	0.60	0.56	0.56	0.04	0.04
418	0.62	0.64	0.58	0.06	0.04
Average..	0.571	0.575	0.558	0.017	0.013

RECLAIMING FAT BY CENTRIFUGAL SEPARATION OF THE BUTTERMILK

It was shown in previous paragraphs that the churning loss under normally efficient conditions of operation is approximately 1.25% of the total fat churned. When applied to the total amount of butter fat churned annually in this country, the total churn loss is equivalent to approximately 20,000,000 lbs. of butter.

Efforts to minimize this enormous loss to the industry by reclaiming a portion of the fat contained in the buttermilk, have led to the separation of buttermilk, using the standard centrifugal cream separator, the whey separator, high speed supercentrifuges, and separators specially designed for skimming buttermilk.

Efficiency of Buttermilk Separation Requires Intensified Centrifugal Force.—In view of the fact that the majority of the fat globules that refuse to churn out and, therefore, pass into the buttermilk, are the smallest globules contained in the cream (less than 2 microns in dia.) the fat of the buttermilk does not respond as readily to the centrifugal force of the separator as does the fat in whole milk with its great predominance of larger size fat globules. Efficient separation of buttermilk, therefore, requires more intense exposure to centrifugal force, such as may be provided by superspeed separators, or by providing means to prolong exposure of the buttermilk to the centrifugal force.

Buttermilk from Sour Neutralized Cream Requires Special Treatment to Prevent Clogging of Separator Bowl.—In the case of sweet cream buttermilk, the mechanism of centrifugal separation is comparatively simple, because of the fine dispersion of the casein particles and absence of coagulated curd, eliminating the tendency of early filling and clogging of the bowl with curd.

In the case of sour neutralized cream buttermilk, centrifugal separation is hopeless on account of the relatively large particles of coagulated casein, which quickly fill up the bowl and clog it, unless the buttermilk is first treated with chemicals that soften or dissolve the curd sufficiently to set free the entrained fat globules and to provide a sufficiently fine dispersion of the casein to permit the buttermilk to pass through the separator without clogging the bowl. In order to accomplish this, the treatment of the buttermilk must be adjusted to the character of neutralizer used. Carbonate alkalies are unsuitable for treatment, because of their casein precipitating tendencies. For buttermilk from cream that was neutralized with soda or soda and lime, an alkali containing caustic soda, or partly changing to caustic soda in the cream, is most suitable. For buttermilk from lime neutralized cream, a chemical with an acid reaction gives the desired solving action to prevent clogging. Ordinary salt (Na Cl) likewise has a limited solving tendency and retards the clogging tendency of buttermilk from lime-neutralized cream.

Experiments in Separating Buttermilk from Sweet Cream.—Thurston and Combs[64] studied the possibilities of separating sweet cream buttermilk. They report that only in two cases they were able to reduce the per cent of fat in buttermilk to a point below 0.4%, and in the majority of cases the test of the separated buttermilk exceeded 0.5%. They point out that where methods for exhaustive churning are used, separation of the buttermilk would seldom reduce the test by more than 0.15%. They, therefore, concluded that separation of buttermilk is commercially practicable only in the case of large volume of buttermilk (in excess of 25,000 lbs. daily), or in the case of excessively large fat content of the buttermilk.

Patented Process for Separating Buttermilk.—Rushton[65] invented a process of separating buttermilk, on which he was granted a U. S. patent, by prolonging the exposure of the but-

termilk to centrifugal force beyond the usual time. He accomplished this by greatly reducing the orifices of the skim milk and cream outlets, bushing them down to a diameter of say one sixty-fourth inch for a disk type separator of a capacity of 3500 lbs. of milk per hour. He claims that, when reducing the separator outlets sufficiently to increase the time of exposure in the separator 20 times, about 55% of the total fat in the buttermilk whey is recovered in the form of a liquid obtained through the cream outlet, testing 2% fat or more.

For sour cream buttermilk Rushton recommends chemical treatment of the buttermilk with alkalies or acids, or coagulants, so as to produce a whey that is sufficiently cleared from casein particles, to prevent clogging of the separator bowl. The patent provides suggestions for suitable arrangement of equipment to operate the process.

Improved Churning Efficiency Eliminates Necessity of Buttermilk Separation.—While there are a few commercial creameries handling large volumes of buttermilk, that have found the separation of buttermilk a profitable enterprise, especially in the case of high testing buttermilk, the present status of buttermilk separation has such limitations of practicability as to emphasize the importance and the advantage of concentrating on methods that make for maximum churning efficiency, rather than depending on buttermilk separation to avoid excessive fat losses.

REFERENCES

1. North, G. C., and Sommer, H. H., J. D. Sc. XVIII, *1*, 21, (1935).
2. Jack, E. L., and Dahle, C. D., J. D. Sc. XX, *10*, 637, (1937).
3. Mohr, W., and Brockman, C., Milchw. Forsch. XI, *21*, 6, (1930).
4. Sommer, H. H., and North, G. C., Abstr. 28th Ann. Meet. Am. Dairy Sci. Assoc. 49, (1933).
5. Bird, E. W., Breazeale, D. F., and Bartle, E. R., Ia. Agr. Expt. Sta. Res. Bul. 227, (1937).
6. Storch, V., Milch Ztg., (1897).
7. Palmer, L. S., and Samuelson, E., Proc. Soc. Expt. Biol. Med. XXI, 537, (1924).
8. Wiese, H. F., and Palmer, L. S., J. D. Sc. XV, *5*, 371, (1932).
9. Palmer, L. S., and Wiese, H. F., J. D. Sc. XVI, *1*, 41, (1933).
10. Wiese, H. F., and Palmer, L. S., J. D. Sc. XVII, *1*, 29, (1934).
11. Rimpila, C. E., and Palmer, L. S., J. D. Sc. XVIII, *12*, 827, (1935).
12. Völtz, W., Arch. Ges. Physiol. (Pflügers) *103*, 373, (1904).
13. Abderhalden, E., and Völtz, W., Zeitschr. Physiol. Chem. *50*, 13, (1909.)
14. Titus, R. W., Sommer, H. H., and Hart, E. B., J. Biol. Chem. *76*, 237, (1928).
15. Jack, E. L., and Dahle, C. D., J. D. Sc. XIX, 476, (1936).
16. Holm, G. E., Fundamentals of Dairy Sci. VII, 166, (1935).
17. Rahn, O., and Sharp, P. F., Physik der Milchwirtschaft, (1928).
18. Weinlig, A. F., see Fundamentals of Dairy Sci. VII, 178, (1935).

19. HUNZIKER, O. F., Blue Valley Cry. Co., (not publ.), (1929).
20. VAN DAM, WM., Proc. World Dairy Cong. II, 1004, (1923).
21. ARUP, P. S., Analyst *53,* 641 (1928).
22. QUAGLIARIELLO, G., Abst. Milchw. Forsch. *7,* 31, (1929).
23. KING, N., Kolloid-Zeitschr. LII, *3,* 319, (1930).
24. VAN DAM, W., and BURGERS, W. G., J. D. Sc. XVIII, *1,* 45, (1935).
25. RAHN, O., Milchw. Forsch. III, 5-6, 519, (1926).
26. PALMER, L. S., J. D. Sc. V, 201, (1922).
27. FISCHER, M. H., and HOOKER, M. O., Fats and Fatty Degeneration, (1917).
28. KING, N., Zeitschr. f. Milchw. Forsch. VIII, 1-2, 95, (1928).
29. HUNZIKER, O. F., Blue Valley Res. Labs. (not publ.), (1934).
30. HUNZIKER, O. F., Blue Valley Res. Labs. (not publ.), (1920).
31. HUNZIKER, O. F., MILLS, H. C., and SPITZER, GEO., Purdue Agr. Expt. Sta. Bul. 159, (1912).
32. HAGELUND, E., WODE, G., OLSSON, T., Centralanst. Forsoksv. Jordbruksomradet Meddel. 387, (1930).
33. COULTER, T. S., and HILL, O. J., J. D. Sc. XVII, *8,* 543, (1934).
34. BROUWER, E., Chem. Abstr. *27,* 4956, (1933).
35. HANSEN, A. P., STEENSBERG, V., 9th Beretning fra Statens Forsogsmeferi *95,* (1931).
36. LYONS, J., Econ. Proc. Roy. Dublin Soc. *3,* 19, (1936).
37. HILDITCH, T. P., and SLEIGHTHOLME, J. J., Biochem. Jour. *25,* 507, (1931).
38. MONTI, N., Le Lait *15,* 609, (1935).
39. STOUT, R. E., Ore. State College, M. S. Thesis, (1939).
40. ECKLES, C. H., and SHAW, R. H., U. S. Dept. Agr. Bul. 156, (1913).
41. ARUP, P. S., Analyst *57,* 610, (1932).
42. DEAN, H. K., and HILDITCH, T. P., Biochem. Jour. *27,* 889, (1932).
43. HANSSON, N., and OLOFSSON, N. E., C. A. *25,* 4631, (1931).
44. HANSSON, N., and OLOFSSON, N. E., C. A. *26,* 3048, (1932).
45. ARUP, P. S., Analyst *54,* 634, (1929).
46. STOUT, R. E., and WILSTER, G. H., J. D. Sc. XXII, *6,* 424, (1939).
47. HILL, O. J., and PALMER, L. S., J. D. Sc. XXI, *9,* 529, (1938).
48. RICHARDSON, G. A., and ABBOTT, F. H., Proc. 21st Ann. Meet. West. Div. Am. Dairy Sc. Asso., Portland, Ore., 63, (1935).
49. HANSEN, H. C., and SHAW, A. O., Proc. 23rd Ann. Meet. West. Div. Am. Dairy Sc. Asso., Portland, Ore., 46, (1937).
50. MOORE, J. S., 44th Ann. Rept. Miss. Agr. Expt. Sta. 22, (1931).
51. CRASEMANN, E., and WIDMER, A., C. A. *30,* 4576, (1936).
52. STOUT, R. E., and STEIN, R. W., 24th Ann. Meet. West. Div. Am. Dairy Sc. Asso., (1938).
53 ECKLES, C. H., and PALMER, L. S., Mo. Agr. Exp. Sta. Res. Bul. 24, (1916).
54. SHAW, R. H., and ECKLES, C. H., U. S. Dept. Agr. Bul. 111, (1909).
55. ECKLES, C. H., and SHAW, R. H., U. S. Dept. Agr. Bul. 155, (1913).
56. BIRD, E. W., and DERBY, H. A., Ia. Agr. Expt. Sta. Res. Bul. 214, (1937).
57. COMBS, W. B., and COULTER, S. T., Minn. Agr. Expt. Sta. Bul. 273, (1930).
58. KRUKOVSKY, V. N., and SHARP, P. L., J. D. Sc. XIX, *4,* 279, (1936).
59. HUNZIKER, O. F., and CORDES, W. A., Blue Valley Res. Labs. (not publ.), (1938).
60. RUEHE, H. A., and STIRITZ, B. A., J. D. Sc. VIII, *4,* 330, (1925).
61. BIRD, E. W., Nat. Butter and Cheese Jour. XXX, *1,* 16, (1939).
62. BOUSKA, F. W., The World's Butter Review, *9,* Dec. (1927).
63. BIRD, E. W., BREAZEALE, D. F., and SANDS, G. C., Ia. Agr. Expt. Sta. Res. Bul. 175, (1935).
64. THURSTON, L. M., and COMBS, W. B., Dairy Record Nov. 24 and Dec. 1, (1926).
65. RUSHTON, A. L., U. S. Patent No. 1,683,728, (1928).

CHAPTER XVI

WASHING, SALTING AND WORKING

WASHING THE BUTTER

Purpose.—The chief object of washing is to free the butter granules from such remnants of buttermilk as adhere to their surface and as may be entrained in the interstices between the granules, and to eliminate from the churn all loose buttermilk present. Other objects that may be at least partially accomplished by washing are, to correct defects in the firmness of the butter by the proper adjustment of the wash water temperature, and to lessen the intensity of certain off-flavors in the case the original cream was of poor quality.

Adding the Wash Water.—After the buttermilk has been drawn off and the butter allowed to drain, the churn is ready for the properly tempered wash water. Under average normal conditions the use of an amount of wash water approximately equal to the volume of the buttermilk is adequate for butter made from cream of good quality. This means about 150 to 200 gallons of water per average size churning of 800 to 1000 lbs. of butter. For undergrades two such washings are preferable.

In order to expedite the operation and facilitate the removal of remnants of buttermilk, it has been found helpful to spray about one-fourth (30 to 50 gals.) of this water over the butter, with churn gate open, until the discharge appears real watery, then close the churn gate. When the remainder of the wash water is all in the churn, the churn doors are closed and the churn is given a few (3 to 5) revolutions in low gear, after which the water is drawn off, unless the particular condition of the butter makes it desirable to hold the butter in the wash water for a while. In the absence of spraying with churn gate open, the wash water is best added in two installments with churn gate closed, giving the churn a few revolutions with each installment of water.

Thoroughness of Washing.—The proportion of the buttermilk constitutents contained in the butter, such as curd, acid and ash, that can be removed by washing, is limited to the buttermilk

that adheres to the surface of the butter granules and that is entrained between the granules. The buttermilk contained in the interior of the butter granules, i. e., that has been churned into the butter granules during their formation in the churning process, is so finely dispersed within the granules and so thoroughly incorporated that it is not reached nor removed by the wash water.

It is for this reason that the washing of butter does not decrease the so-called curd content of the butter as much as the clearness of the draining washwater would logically suggest. Comparative analyses of washed and unwashed butter by Hunziker[1] suggest that approximately 25% of the curd contained in the unwashed butter is removed by washing. These results are in general agreement also with the values reported by Hittcher,[2] who found a reduction in curd content due to washing of 15 to 27%.

The researches of Boysen,[3] Rahn and Boysen,[4] and Collins and Hammer[5] indicate that there is practically no migration of bacteria between the water droplets in the interior of well worked butter at rest. The calculations of Rahn and Boysen show that the minute droplets of buttermilk which are incorporated in the interior of the butter granules during the churning process are so small and so numerous, in comparison with the number of bacteria contained in cream at churning time, that all these droplets cannot possibly contain bacteria and that, in fact, even in butter made from ripened cream, the vast majority of these small droplets (about 99.5%) are sterile. Failure on the part of the wash-water to remove the buttermilk that was originally churned into the interior of the butter granules in the form of these exceedingly small droplets, therefore, does not necessarily jeopardize flavor or keeping quality.

Washing also decreases acid formation in butter. Rahn and Boysen found this decrease in acid formation much greater than would be expected from the relatively large amount of protein and lactose left in the washed butter. They account for this observation on the basis of the almost complete separation of the bacteria from their food supply in the case of thoroughly washed and properly worked butter.

Excessive Washing Uneconomical.—The experimental results and conclusions cited above are supported by practical experience in commerical butter manufacture, to the effect that

unwashed butter that contains enough loosely-held buttermilk to show a milky "tear," invariably has poor keeping quality, and that the proper washing of butter with pure water, that eliminates the removable, free buttermilk, retards bacterial flavor deterioration and improves keeping quality. These facts have led some enthusiasts to recommend using three or four washings with amounts of water approximately equal to the volume of the cream churned, for each washing. Such profuse washing, however, is neither necessary nor desirable. Two washings will eliminate so large a portion of the removable buttermilk that the possible benefit, if any, of further washing is too limited to justify the cost of equipment and expense of operation involved in providing such large volumes of properly tempered water.

Washing of Unsalted Butter.—Furthermore, excessive washing does not necessarily always make for maximum keeping quality. Under certain conditions it may, in fact, tend toward a hastening of deterioration. This effect is particularly noticeable in the case of unsalted butter made from properly ripened cream. When profusely washed, much of the pronounced flavor character passes into the wash water and is lost to the butter. The preservative properties developed in ripening, such as predominance of lactic acid bacteria, lactic acid, and lactates, are dissipated, and resistance to flavor-damaging bacterial deterioration is diminished. Such butter usually shows a washed-out, flat flavor and lack of aroma, soon yielding to a stale flavor, followed by cheesy flavor. On the other hand, unsalted butter made from the same ripened cream, when washed sufficiently only to avoid the appearance of a milky tear, resists bacterial deterioration better and retains its fresh flavor longer. Lightly washed unsalted butter, made from ripened cream, has better keeping quality than excessively washed unsalted butter made from the same cream.

In this consideration of the possibilities and limitations of the benefits of "washing," the recent experimental results of the Danish Experiment Station at Hillerod, Denmark, referred to in more detail later in this Chapter, are of added significance. In this case the butter was made in an all-metal churn with multiple buttermilk outlets that permitted the buttermilk to drain from every position of the churn. The butter was warmed for working and was sufficiently soft at the finish to be forced

out of the churn into the firkin by a few pounds of air pressure. This butter had the best quality when not washed at all. Obviously these remarkable results had a background of minimum bacterial contamination, made possible by a sterilizable all-metal churn and automatic transfer from churn to firkin; of maximum elimination of buttermilk made possible by a system of multiple buttermilk outlets; of separation of bacteria from food supply by emulsification of the warm butter to an exceedingly small particle size of moisture droplets, and by complete absence of dilution that would dissipate the preservative properties (lactic bacteria, lactic acid, lactates) inherent in properly ripened cream.

Heavy Washing of Undergrades.—In the case of butter of poor quality, heavy washing tends in the direction of improved flavor and keeping quality. The flavors present in such butter are largely objectionable, and the buttermilk is pregnant with products of decomposition that encourage progressive spoilage. Such butter has nothing to lose and everything to gain by thorough washing. While no amount of washing will improve its quality very greatly, thorough washing will help to minimize the intensity of off-flavors, to eliminate some of the damaging products present, and possibly to retard deterioration somewhat. Its general effect here is favorable rather than otherwise.

Temperature of Wash Water.—The temperature of the wash water has a marked effect on the firmness and texture of the butter and on the readiness with which the butter takes up moisture. For suitable facilities for tempering the wash water see "Water Supply for Washing the Butter," Chapter III. Under normal conditions, and with butter granules of the desired firmness, it is customary to have the wash water at a temperature a few degrees (about 2 to 4° F.) below the temperature of the buttermilk. This corresponds with the approximate original temperature of the cream in the churn.

Since lower temperatures harden, and higher temperatures soften the butter, it has been the general practice of the buttermaker to use lower wash water temperatures in summer, when the butter is inclined to be excessively soft, and to use higher wash water temperatures in winter when the natural tendency is for the butter to be excessively hard and crumbly. When the wash water temperature used is much higher or much lower than the temperature of the buttermilk, it is good practice to

hold the granular butter in the wash water for 10 to 20 minutes, in order to accomplish uniform tempering of all the butter in the churn.

Extensive study of the factors controlling the firmness and consistency of butter by Mohr and Oldenburg[6] has revealed a new aspect regarding the influence of the temperature of the wash water on the body of the butter. While agreeing with the long established, general observation that cold wash water hardens and warm wash water softens the butter in the churn, they found that the opposite effect is the case after the butter has been at rest long enough (in ordinary cooler at 45 to 50° F. for 24 hours) to insure adequate progress of fat crystal formation. Their results show definitely that after 24 hours butter that was washed at a temperature of 10 to 14° C. (50 to 57° F.) has a firmer body than butter washed at 3 to 5° C. (37.4 to 41° F.). These findings are supported by well established observations of the mechanism and phenomena of crystal formation. For detailed explanation see Chapter XV under "Effect of Cooling the Cream Preparatory to Churning," and Chapter XXIII under "Seasonal Defects of Body and Texture of Butter."

On the basis of the above results Mohr and Oldenburg recommended that, in order to avoid an excessively hard and crumbly body in winter butter, wash water at a temperature below 6° C. (42.8° F.) be used, and to make summer butter of satisfactory firmness, the wash water be at as high a temperature as feasible, consistent with sufficient firmness of the butter granules at the time of working to avoid leakiness of the finished butter. This temperature they found to be approximately 11° C. (52° F.). The above principle of effect of wash water temperature on permanent firmness of butter, projected by Mohr and Oldenburg, is supported by the later findings of Coulter and Combs.[7]

Effect of Wash Water Temperature on Moisture Content of Butter.—High wash water temperature tends to raise the moisture content of the butter. The higher the temperature the greater the softening effect on the butter granules. Soft butter granules tend to mat together and refuse to drain readily. In this condition they retain more moisture. Excessively warm wash water, therefore, may lead to high moisture. This soft condition of the butter granules may also result in objectionably leaky butter, due to its refusal to permit of normal working.

Purity of Wash Water.—The water used for washing butter should obviously be pure. It should be free from sand and roily material, from objectionable mineral and organic matter, and its microbiological status should be such as to pass examination by health authorities.

Roily Wash Water.—Water that contains sand or roily material, such as silt, is unfit for use because butter containing such foreign matter is unmarketable. Water from a newly drilled well often contains sand that will disappear after pumping for a few days or weeks. In the case of deep well water that is otherwise of satisfactory purity, persistent sandiness may be prevented by consulting an experienced well man. Silt, such as may be in river water at times of freshets, or roiliness due to repairs in the water supply line, is difficult to remove. Such water requires the use of an efficient filter before it is fit to use.

Chemical Impurities in Wash Water.—Water containing volatile sulphur compounds, such as sulphides, will taint the flavor of the butter and should be condemned. Other mineral impurities, such as iron, manganese, etc., when present in considerable amounts, are considered objectionable, although such limited data[8, 9, 10] as are available, fail to show any noticeable detrimental effect on flavor and keeping quality of butter.

Bacterial Impurities in Wash Water.—The microbiological purity of the water used for washing butter is of very great importance in the control of the flavor and keeping quality of the butter. Bacteriologically impure water may and often does cause the type of contamination that may lead to the most disastrous bacterial flavor defects, such as putrid flavor (surface taint), rancidity and the like. It is wisdom on the part of the buttermaker, therefore, to make sure that his water supply for washing the butter is bacteriologically safe. Water with a high total count may reasonably be looked upon with suspicion. A high count is usually associated with a high content of organic matter, and the usual sources of organic matter in water supply are logical breeding places for the quality-damaging type of germ life.

The cause of bacterial pollution of the water may be at the source of the water supply, or it may be due to conditions in the factory. Water from shallow wells, either open or drilled, is readily contaminated by surface water and seepage from

cesspools, cemeteries and the like. River water, especially at low water time, is prone to be relatively high in organic matter, particularly in case of industrial refuse farther up the river. Water from deep wells as a whole, may be expected to be low in organic matter and in bacterial count. Only in exceptional cases is the combination of slope of strata, topography and condition of surroundings such as to cause objectionable seepage to contaminate deep well water. Water from municipal corporations in towns of sufficient size to operate an efficient water treatment system, is practically invariably suitable for washing butter.

Bacterial Contamination of Wash Water in the Factory.— Not infrequently the source of the high bacterial count lies in the plant itself. Dead ends in the water line may harbor stagnant water teaming with germ life and that is a constant feeder of contamination of the water supply. The sweet water tank in which the water is cooled and the tempering tank used for adjusting the wash water temperature may have become coated with slimy material of high bacterial count. Such conditions are definitely known to have led to disastrous bacterial flavor defects in butter. Dead pipe ends should be permanently eliminated and tanks in which the water is tempered or stored should be completely emptied, thoroughly cleaned, and flushed out at reasonably frequent, regular intervals, to keep them free from deposits and accumulations of organic and mineral matter. In order to keep sediment out of the water that goes to the churns it is helpful to equip the outlet of these water holding and tempering tanks with a removable sleeve of fine wire mesh. Brine or ammonia coils in these tanks are preferably painted with suitable paint, so as to avoid rusting and the consequent pollution of the water with iron rust.

Treatment of Water to Make it Safe Bacteriologically.— Whenever there is reasonable doubt as to the bacterial purity of the wash water, it is wisdom to provide a suitable method for treating the water to eliminate or make harmless the germ life the water may contain. The several forms of treatment that have been found practicable under average creamery conditions are: filtration, pasteurization or sterilization by heat, chemical treatment, ultra-violet ray treatment. These treatments and their respective merits are briefly discussed as follows:

Filtration.—Various types of filters have been used in efforts to remove microrganisms from the water intended for washing the butter, by the process of filtration. The efficiency of most of them has proved somewhat uncertain. Bacterial analyses of filtered water have shown variable results, probably depending to a considerable extent on the type, care and condition of the filter used. However, Olson[24] reported that unsalted butter washed with filtered water (using a Seitz filter), had better keeping quality than when washed with unfiltered water. The use of such a filter would improve the purity of the available water supply in the majority of creameries and would provide added protection of the butter from damaging contamination.

Nor does absence of an efficient water filter eliminate the need of some suitable means for straining the water for the purpose of keeping sand, silt, scales from pipes, and diverse chance objects out of the churn and the butter. The water for washing the butter should be strained into the churn through heavy, fine-mesh cloth, or special filter pads that can be daily washed, or renewed at small cost. The importance of such straining cannot be overemphasized in efforts to eliminate the water as a potential source of extraneous matter in butter. However, strainers of fine-mesh cloth should not be expected, nor depended upon to render the wash water safe bacteriologically.

Pasteurization or Sterilization by Steam.—This type of treatment is entirely practicable and can be made very effective. The regular cream pasteurizing equipment may be used for this purpose. Or, the water may be heated in a special tank with "live" steam or with regenerative coils and exhaust steam. The cost of pasteurization and cooling of the water used for washing the butter has been variously estimated. In the case of two washings per churning it was found to average approximately between one-quarter and one-half cent per pound of butter. Experiments comparing the keeping quality and market value of butter washed with pasteurized water and with untreated water, respectively, point definitely in favor of pasteurized wash water. The pasteurization or boiling of the butter wash water tends toward improved general keeping quality and is an effective precaution against specific flavor defects caused by contamination with the usual putrefactive species that have been found in

polluted water. In order to secure the full benefits of this treatment, the water should be pasteurized on the day it will be used. Holding it at ordinary temperature causes rapid mutiplication of the germs that survive the heat treatment.

Chemical Sterilization.—In case of uncertainty as to the bacterial purity of the water available for washing the butter, and in factories not prepared to pasteurize the water, it may readily be rendered harmless by chemical sterilization. For this purpose chlorination is recommended. The addition of one pint of a 3% chlorine solution to 150 gallons of water gives the water a chlorine content of approximately 25 p.p.m. For best results the chlorine should be added to the water from 15 to 30 minutes before running the water into the churn, in order to permit complete action of the chlorine on the germ life in the water. Water so treated is practically sterile and has no objectionable effect on the flavor of the butter.

In the place of chlorination satisfactory germ destruction may also be accomplished by making the water alkaline with sodium hydroxide to a pH value of 10.8 to 11.1, allowing the alkaline water to stand for 1 to 1½ hours and then adding enough hydrochloric acid to bring the water back to the neutral point, as recommended by Virtanen and Karstrom.[11]

Ultra-Violet Ray Treatment.—The ultra-violet ray process of treating water has been found very suitable for the sterilization of drinking water, water for swimming pools, etc. Its efficiency has been dependably established by government tests[12]. The initial expense of equipment needed for water sterilization by means of the ultra-violet ray method, and the cost of operation are as yet beyond the reach of the average creamery. Its use would provide, however, a simple and dependable safeguard against the dangers of a questionable water supply for creamery use.

Water Supply from Municipal Corporations.—Creameries located in large towns and cities usually have access to the water supply of the local municipal corporation. This often solves the problem of pure water for them. But, even these favorable facilities, do not eliminate the need of a good water strainer, nor the advisability of an occasional check-up on the bacterial count of the water.

SALTING THE BUTTER

Purpose.—The chief objects of adding salt to the butter are to improve its keeping quality and to satisfy the requirements of the trade. In countries whose legal butter standards are confined to a maximum moisture limit and who do not have a minimum fat limit, the salting of butter may serve also as a means to increase the overrun.

Effect of Salt on Keeping Quality of Butter.—The original object for which salt was added to the butter was to preserve it. This was the case in the days of farm buttermaking, when butter was made from raw cream and before the advent of artificial refrigeration and commercial cold storage. The salt is capable of influencing the keeping quality of butter in two ways, namely, bacteriologically and chemically.

Bacteriological Influence of Salt.—The antiseptic and preservative properties of salt are generally known and recognized. Salt, in concentrated solution, is capable of inhibiting the growth of microorganisms. The salt in butter is present in the water portion. It is, therefore, the concentration of the salt in the serum of butter that controls the inhibiting effect of salt on the microorganisms present. The salt concentration in the water portion for butter of a salt content ranging from 0.5 to 3.5% salt is shown in Table 34.

Table 34.—Relation of Percentage of Salt in Butter to Salt Concentration in Water Portion, When Working to 16% Moisture Limit and to 80% Fat Standard, Respectively

Salt in Butter	16% Moisture Limit			80% Fat Standard Only		
	Moisture	Total Moisture and Salt	Concentration of Salt in Water Portion	Moisture	Total Moisture and Salt	Concentration of Salt in Water Portion
%	%	%	%	%	%	%
3.5	15.5	19.0	18.4	15.5	19.0	18.4
3.2	15.8	19.0	16.8	15.8	19.0	16.8
3.0	15.8	18.8	16.0	16.0	19.0	15.8
2.5	15.8	18.3	13.7	16.5	19.0	13.1
2.0	15.8	17.8	11.2	17.0	19.0	10.5
1.5	15.8	17.3	8.7	17.5	19.0	7.9
1.0	15.8	16.8	5.9	18.0	19.0	5.2
0.5	15.8	16.3	3.1	18.5	19.0	2.6

All figures in table 34 are based on a minimum fat standard of 80%, allowing 1% for the constituents other than moisture and fat, which are usually expressed arbitrarily as curd. The values in the left half of the table refer to butter that must conform to a 16% moisture limit and it is assumed that this butter would be worked to an average moisture content of approximately 15.8%. The total of moisture and salt in such butter, therefore, decreases with the decrease in the salt content. The values in the right half of the table refer to butter, the moisture content of which is limited only by the 80% fat standard. The total moisture and salt is, therefore, maintained at the maximum of 19%, the decrease in salt content being compensated for by a corresponding increase in moisture content.

Experimental data show that at temperatures at which most organisms found in butter are capable of growing (above 32°F.), total counts of bacteria, yeast and molds increase in unsalted butter, while they tend to decrease in salted butter.

The germ counts of Macy[13], given in Table 35, may serve to illustrate the effect of salt, showing a definite increase in total mold, yeast and bacteria count in unsalted butter and a large decrease of yeasts and bacteria in salted butter, during 30 days after manufacture.

Table 35.—Total Counts of Molds, Yeasts and Bacteria

Age of Butter	Salted Butter			Unsalted Butter		
	Molds	Yeast	Bacteria	Molds	Yeast	Bacteria
When Fresh....	19	295	260,000	25	169	230,000
1 Month Old....	25	59	77,000	340	210	2,100,000

In general, these findings are supported by commercial experience, as well as by experimental results to the effect that at ordinary temperatures, salted butter has better keeping quality, as related to freedom from flavor deterioration caused by bacterial action, than does unsalted butter.

The above general fact relating to the effect of salt on total germ counts in butter, however, does not eliminate the possibility and the danger of bacterial deterioration of salted butter. Microorganisms differ in their tolerance toward salt and toward different concentrations of salt. Some species become gradually atten-

uated to salt media, some thrive in weak salt solutions and some are not inactivated by fairly strong salt concentrations. While butter containing 3% salt seldom, if ever, yields to serious flavor deterioration, due to bacterial causes, butter containing 2.5% salt or less is not immune to such disastrous bacterial defects as rancidity and surface taint (putrid flavor). At 2.0% or less salt the tendency for the development of cheesy flavor increases.

Chemical Effect of Salt.—Chemically the salt tends to hasten the deterioration of butter. This deterioration is most pronounced and most rapid in the presence of acid. Chemical flavor deterioration generally is gradual, but it progresses at any temperature, even at the low temperatures of commercial cold storage. Because of its relatively slow progress, it is more apparent in cold storage butter than in short-held butter. The salt appears to materially hasten protein decomposition. High salt content causes more intense and more rapid chemical flavor deterioration in storage butter than low salt content.

These experiences suggest that salt complicates the composition and reactions in storage butter, diminishes its chemical stability, and hastens the changes that are responsible for flavor deterioration at temperatures that preclude the possibility of bacterial action. They further emphasize the fact that high salt content is more conducive to such flavor deterioration than low salt content of butter.

Effect of Salt on Flavor of Butter.—The majority of the consuming public in America prefer the seasoned flavor of salted butter to the flatter flavor of unsalted butter. The average consumer demands salted butter.

Excessive salt, however, damages flavor and jeopardizes consumer demand. In heavily salted butter the salt tends to hide and partially destroy the delicate flavor and aroma that is characteristic of butter of high quality. A really fine quality butter, such as butter scoring 93 points and higher, or prize-winning butter at a scoring contest, is not high salt butter. Nor does a high salt content (over 2.5% salt) cover up objectionable flavors, as is popularly assumed. On the contrary, such flavors are made more prominent by the salty taste. Instead of hiding them, the salt intensifies them and gives the butter a disagreeable, coarse flavor character. In fact, butter made from second grade cream is more palatable and sells to better advantage when not salted at all.

Aside from the actual amount of salt present, the completeness of its solution and the permanency of dispersion of the brine in the butter influence the intensity of the salty flavor to a marked degree. Gritty butter, because of the presence of undissolved salt crystals, and leaky butter because of the presence of free brine, magnify the salty taste and tend to give the butter a sharp, coarse briny flavor that is objectionable.

Effect of Salt on Texture, Moisture and Color of Butter.—The addition of salt disturbs the dispersion of the moisture in butter. This, in turn, changes the texture and alters the color of the butter.

When cream is churned under conditions that produce butter of normal firmness, the unsalted, unworked butter granules have a compact body and waxy texture, and the bulk of the moisture associated with the granules is present in the form of myriads of very minute droplets, finely and evenly dispersed throughout the butter granules. These small moisture droplets are enmeshed in the mass of fat and the colloidal material that was carried into the butter during the churning process. The presence of this great multitude of dispersed microscopic moisture droplets gives the butter an opaque appearance and a relatively light creamy color. This butter also contains some more loosely held moisture droplets, more or less unevenly dispersed.

Salt Changes Size of Moisture Droplets.—The addition of salt definitely changes the picture of this butter. The salt, owing to its affinity for water, draws the less firmly held water droplets together, forming drops and larger aggregates. This unstabilizing action on the moisture dispersion by the salt is further facilitated by the "salting-out" reaction on the protein colloidal material. The action makes for precipitation, contraction, dehydration, loss of viscosity, and diminished moisture-holding ability.

The compact waxy texture changes to a coarser, more open and leaky structure, and the densely opaque, light creamy appearance gives way to a more translucent, clear and deeper yellow color. A larger portion of the moisture in this salted butter is present in the form of larger droplets and drops less firmly held in the structure of the butter. The size of moisture droplets in salted and unsalted butter partially worked was experimentally determined by Boysen[3], whose average results of two comparable series of experiments are given in Table 36.

Table 36.—Effect of Salting on Proportion of Different Size Moisture Droplets in Butter.

Size of Water Droplets	Before Salting	After Salting
	Number of Droplets	Number of Droplets
Microns	Per Cent	Per Cent
1-15	11.59	6.96
15-100	1.49	1.32
Over 100	.92	4.33
Total Moisture Content %............	14.00	12.62

The above table shows that the addition of salt to butter decreased the proportion of small water droplets and greatly increased the proportion of large droplets and drops of moisture in butter.

Salted Butter Loses More Moisture During Storage.—While proper working will prevent leakiness in salted butter, yet the tendency toward loss of moisture in storage is greater with salted butter than with unsalted butter, and it is greater in heavily salted butter than in light-salt butter. Experience in commercial butter manufacture of the effect of salt on loss of moisture in butter is supported by the results of numerous experimental comparisons. Thus Rahn, Brown and Smith[18] found that salted butter loses more moisture in storage than unsalted. Hunziker, Mills and Spitzer's[19] work showed that in butter held in cold storage (—6° F.) there was no moisture loss in unsalted butter, but an increasing loss in salted butter with increasing salt content. Dahlberg[20] reported that the loss by leakage in butter with 2.3% salt was 1.079%, while butter with 4.1% salt lost 2.28% moisture. Washburn and Dahlberg[15] showed an average moisture loss of 2.51% in butter averaging 2.65% salt, held in storage at —15° F. for 248 days, while their moisture loss in unsalted butter averaged 0.19%.

Salt Intensifies Yellow Color of Butter.—As previously stated, salted butter is less opaque and darker in color than unsalted butter. In the absence of sufficient working and uniform working, causing an uneven distribution and wide range in size of moisture droplets, salted butter will lose its solid, uniform

color and will show mottles or streaks and waves. For details see Chapter XXIII under "Defects in the Color of Butter."

Amount of Salt to Add.—The amount of salt that is added to butter depends primarily on market requirements. These vary between different countries and between different sections of the same country. Such terms as light-salt butter and heavy-salt butter, in fact, may refer to widely different salt contents in different countries.

American markets, as a whole, are accustomed to a relatively high salt content in comparison to European markets, although the trend on the North American continent is toward a lighter salt butter than has been supplied in the past. Our eastern markets, as a whole, call for light-salt butter. This refers to butter containing about 1.5% salt. Our middle western and far western markets are largely supplied with butter of what is considered medium salt content, averaging between about 2 and 2.5% salt. Our southern markets call for the highest salt butter, such as butter with about 3% salt. The Jewish trade demands unsalted butter.

The English markets and continental Europe prefer a much lighter salted butter, such as butter with a salt content of 0.5% to 1.0%. Especially continental Europe looks upon more than 1.0% salt as high-salt butter. In many sections of Continental Europe, such as in France, Southern Germany and Switzerland, the demand for unsalted butter far exceeds that for salted butter.

High Salt Content Decreases Consumption of Butter.—With reference to an abnormally high salt content of butter, such as much in excess of 3%, it is usually not so much a question of market requirements, as it is a question of salt tolerance. It appears safe to assume that, exceedingly remote exceptions reserved, there is not a market anywhere that demands butter with a salt content in excess of 3 to 3.5%. The consumers in some markets, however, are less critical than those in others, and they may tolerate a higher salt content without complaint, than other groups of consumers. Since salt is cheaper than butter fat, the tendency is for these non-critical markets to be provided with high salt butter. In general, the practice of loading the butter with salt penalizes the industry, as it tends to decrease the consumption of butter.

Uniformity of Salt Content Important.—The salt content of butter for one and the same market should be uniform. Uniformity of salt content is important to satisfy the trade and to avoid complaints from the consumer. Variations in the salt content are detected by the consumer more readily than similar variations of any other ingredient in butter. In order to produce butter with a uniform salt content from churning to churning, there is need of standardizing on a definite and accurate system of calculating the correct amount of salt required for any size churning.

Calculating Pounds of Salt Required.—The amount of salt that must be added to the churn to insure the desired salt content in the finished butter is most conveniently and most accurately calculated on the basis of the pounds of fat in the churn, as determined by multiplying the pounds of cream by the per cent of fat. The ratio of salt to fat is determined by multiplying the per cent salt desired in the butter by 1.25. This gives the pounds of salt that must be added for every 100 lbs. of fat in the churn. The result, multiplied by the total pounds of fat present and divided by 100, yields the pounds of salt required.

Example:

850 lbs. of fat are in the churn. Butter is to contain 2.0% salt. How much salt must be added to the churn?

Answer:

Pounds of salt per 100 lbs. fat $2.0 \times 1.25 = 2.5$ lbs. salt

Pounds of salt to add to churn $\frac{2.5 \times 850}{100} = 21.25$ lbs. salt

Salt Losses in Working.—The above calculations are based on the assumption that all the salt added is incorporated in the butter. They make no allowance for salt lost. The salt losses vary considerably according to the manner and completeness of draining, and the method of moisture control. If the method involves draining of the butter during working after salting, the salt losses are obviously high. For minimum loss, the granular butter should be drained thoroughly after washing and the amount of water added for moisture control should be determined sufficiently accurately (see "Moisture Control") to have no free water in the churn in excess of that needed for the desired moisture content in the finished butter. This then permits

of working until all the free brine has been completely taken up by the butter by the time the working process is completed. When following this practice, the loss of salt is negligible and, if desired, it may be amply compensated for by adding 0.1% to the per cent salt desired in the finished butter when calculating the salt ratio. In the foregoing example of calculations of salt to add, therefore, this compensation for salt lost yields the following values of the actual amount of salt required for 2.0% salt in butter:

Pounds of salt per 100 lbs. fat $2.1 \times 1.25 = 2.625$ lbs. salt

Pounds of salt to add to churn $\frac{2.625 \times 850}{100} = 22.3$ lbs. salt

Methods of Salting.—The salting of the butter may be done in three different ways. These methods are known as dry salting, wet salting and brine salting.

Dry Salting.—This is the most common method used. The dry salt is sprinkled evenly over the granular butter in the churn, or the butter is brought up on the shelf with the workers in the low gear. The roll of butter is then split with a ladle, forming a trench from end to end, the dry salt is placed into the trench, distributing it evenly over its entire length. The trench is then closed and the butter worked. With butter of normal firmness the dry salting method is entirely satisfactory and adequate to accomplish complete solution of the salt and proper incorporation of the brine. In the case of abnormally soft butter, however, the dry salt crystals may become coated with a film of soft fat before they have opportunity to take up enough water from the butter to insure complete solution during working. This hinders and delays their solution and tends to make the butter gritty.

Wet Salting.—In this method the salt is wetted down before the working begins. This may be done by first distributing the dry salt over the granular butter or in the trench, as explained under "Dry Salting," and then sprinkling or pouring enough water over the salt to thoroughly wet it. Or the salt is wetted before it is added to the butter by adding enough water to it in a tub or pail to make a salt mash. This salt mash is then poured into the trench, the trench is closed and the butter worked. The mash method, however, is somewhat awkward and time consuming. The wet salting method assists in the rapid

solution of the salt and in avoiding the presence of undissolved salt crystals when the working process is completed. It effectively prevents grittiness. In order to minimize moisture control difficulties and loss of salt, it is important to so regulate the amount of water used for wetting the salt as to prevent the presence of more moisture in the churn at the time the working commences than is desired in the finished butter.

Brine Salting.—In this method the salt is added in the form of a saturated solution of brine. This method is practicable only where a very light salt butter is desired. At best, it requires additional suitable equipment, much extra handling and it results in excessive loss of salt. While ideal from the standpoint of complete absence of undissolved salt crystals in the finished butter and of the danger of grittiness, its unavoidable interference with factory operating efficiency renders its suitability for use in commercial butter manufacture questionable.

BUTTER SALTS

Source and Manufacture.—Most of the butter salts available on the North American Continent are now produced by evaporation of brine from artificial brine wells. These brine wells are driven into salt strata, usually located from about 1000 to 2400 feet below the surface. These wells are formed by drilling down into the rock salt and installing a casing and an inner tube. The casing is about 6 to 6½ inches in diameter and ends just below the top of the salt deposit. The inner tube is 3½ to 4 inches in diameter and extends to near the bottom of the salt strata. The brine is obtained by pumping water down through the annular space between casing and tube. This dissolves the rock salt, forming brine which is then forced up through the inner tube. The brine discharge is usually so regulated as to obtain a brine that contains approximately 25% salt. This concentration is slightly below the saturation point.

Methods of Crystallization.—The leading butter salts on this continent are produced by three different methods of crystallization, classified as Grainer Method, Vacuum Process and Ahlberger Process.

The Grainer process is the oldest of the three processes. The brine is evaporated in open vats or tanks, at a temperature below the boiling point (about 180 to 210° F.). The crystals form at

Fig. 66. Hopper crystals of Grainer process

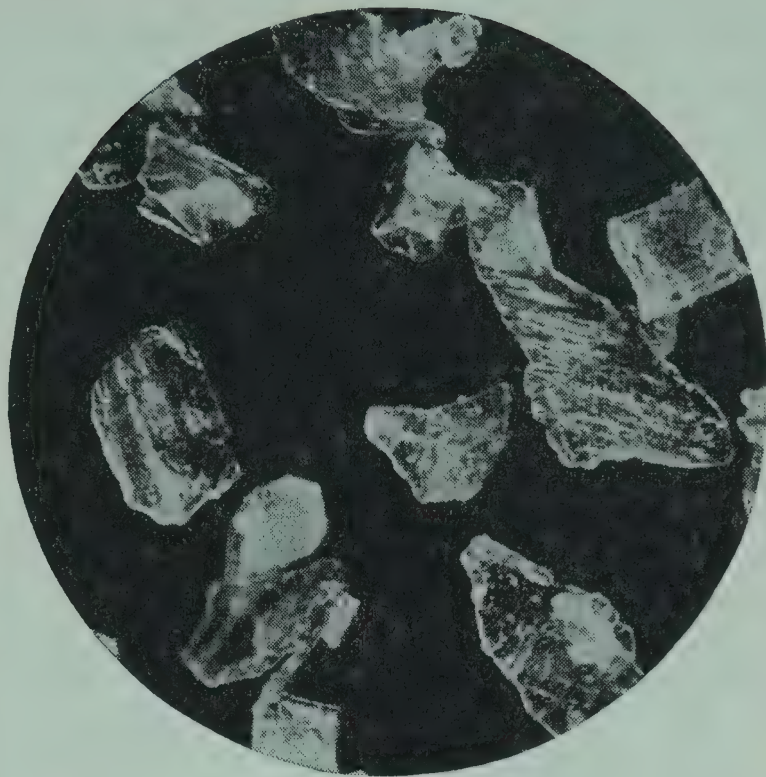


Fig. 67. Flaky grains of broken-down hopper crystals

the surface. They are small cubes which unite into large hopper-like aggregates, sink to the bottom and are scooped out by mechanical rakes. The crystal aggregates are large and coarse. During the drying and screening the aggregates break up and are reduced to flake shape.

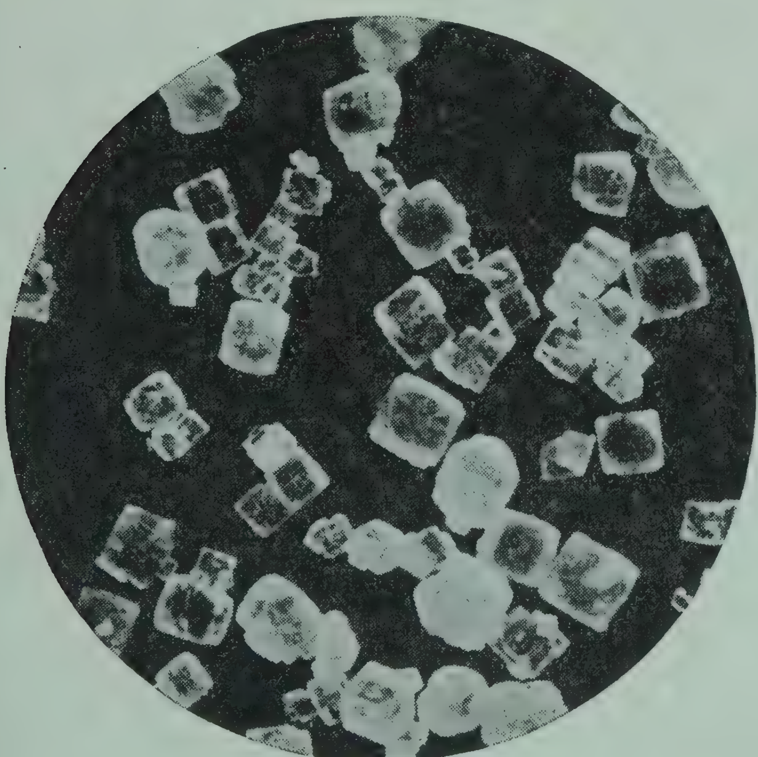


Fig. 68. Cube grains of vacuum process

In the Vacuum process, the brine is evaporated, usually in multiple unit vacuum pans, under reduced pressure and at a correspondingly lower temperature. Solid cube crystals of a somewhat larger size than in the Grainer process form, but be-

cause of the rapidity of evaporation and the violent boiling in the vacuum pan, the vacuum process crystals do not aggregate, but remain independent units. The vacuum salt, therefore, is of small particle size that passes through a finer mesh.

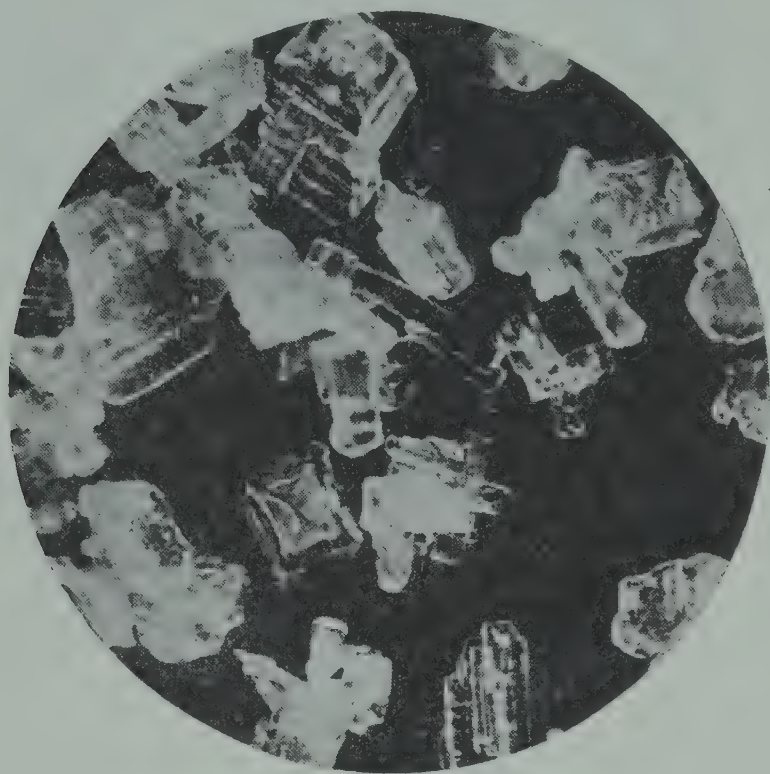


Fig. 69. Salt grains of Alberger process

In the Alberger process, which was developed and is exclusively used by the Diamond Crystal Salt Co., the brine is superheated in a series of tubular heaters. The temperature is raised gradually until it reaches 280° F. or higher, for the purpose of precipitating out mineral impurities such as calcium sulphate (gypsum) which deposits on the tube walls. It then passes through filters or gravellers, which further assist in removing calcium sulphate and, after gradually reducing the pressure, it is released into open circular pans where evaporation and cooling causes mass crystallization. W hile some small cube crystals form before the brine reaches the open crystallizing tank, the major crystallization occurs in this tank and these crystals yield flake salt similarly as in the Grainer process.

Drying, Screening and Packing the Salt.—After removing the crystals from the crystallizing tank, vat or vacuum pan, they are usually centrifuged to remove the bulk of free water. This reduces the moisture content to about 3 to 5%. The final drying is generally done in kilns consisting of hollow revolving cylinders. The heat is supplied by steam pipes or heated air fans or both. From here, the dried salt moves to the screens of vari-

ous meshes, where it is graded according to coarseness. The salt leaves the drier practically devoid of moisture and is packed in paper lined barrels or four-ply paper sacks while still hot.

Chemical Purity of Butter Salts.—A good butter salt should be free from appreciable amounts of mineral salts and oxides other than sodium chloride, of insoluble matter, and of moisture. The salt of the natural salt beds seldom exists in highly pure state.

Table 37.—Chemical Analyses of Nine Butter Salts Manufactured in the United States and Canada (Hunziker et al)

Brand of Salt	Sodium Chloride		Calcium Sulphate	Calcium Carbonate	Calcium Chloride	Magnesium Sulphate	Magnesium Carbonate	Magnesium Chloride	Potassium Chloride	Iron and Alumina	Insoluble Matter	Phosphates	Barium Salts	Moisture
	By Direct Analysis	By Difference												
No.	%	%	%	%	%	%	%	%	%	%	%	%	%	%
1	99.19	99.76	0.073	.....	.....	1.38	.....	.....	....	0.002	0.031	0.00	0.00	0.08
2	98.92	99.58	0.302	.....	0.078	....	.....	0.025	....	0.002	0.008	0.00	0.00	0.105
3	99.48	99.88	0.027	.....	0.048	....	.....	0.041	0.06	0.003	0.004	0.00	0.00	0.140
4	99.11	99.19	0.699	0.046	.....	....	0.027	.....	....	0.008	0.031	0.00	0.00	0.070
5	99.08	99.18	0.756	.....	0.059	....	.....	0.006	....	0.001	0.003	0.00	0.00	0.135
6	98.34	98.59	1.225	.....	0.116	....	.....	0.037	....	0.006	0.027	0.00	0.00	0.125
7	98.67	98.90	0.996	.....	0.060	....	.....	0.026	....	0.002	0.012	0.00	0.00	0.140
8	99.57	99.94	0.038	0.007	.....	....	0.011	.....	0.02	0.001	0.006	0.00	0.00	0.010
9	99.39	99.77	0.197	.....	0.022	....	.....	0.013	....	0.003	0.005	0.00	0.00	0.032

Bacterial Purity of Butter Salt.—Butter salt should be as free from all germ life as possible. Contaminated salt may become the cause of bacterial flavor deterioration of butter. Table 38 gives the results of bacterial analyses by Hunziker, Cordes and Nissen,[21] of samples of salt taken from unbroken barrels of nine different brands.

These figures show that the leading brands of butter salts on the market come from the salines in practically pure condition bacteriologically. The salt is either entirely sterile, or it contains less than 10 germs per gram of salt. This is as might be expected from the treatment given the brine and the salt in the processes of manufacture, and packing.

Table 38.—Bacterial Analyses of Butter Salts

Brand of Salt No.	Bacterial Colonies		Mold Colonies		Total Colonies	
	In 4 Grams	In 1 Gram	In 4 Grams	In 1 Gram	In 4 Grams	In 1 Gram
1	6	1-2	0	0	6	1-2
2	8	2	1	<1	9	2-3
3	3	<1	0	0	3	<1
4	23	5-6	2	<1	25	6-7
5	4	1	4*	1-2	9	2-3
6	5	1-2	0	0	5	1-2
7	6	1-2	1	<1	7	1-2
8	3	<1	1	<1	4	1
9	9	2-3	4	1	13	3-4

*Yeasts.

With the exception of No. 4, the extent of their contamination would be less than one-tenth of one organism per gram of butter. If kept in a dry place and protected against contamination after the package is opened, none of them would be of consequence as a source of butter contamination.

Solubility of Butter Salts.—Salts only that are completely soluble are suitable for butter salt. The solubility of a salt depends chiefly on its chemical purity. Pure sodium chloride is 100% soluble. It was shown in Table 37 that the insoluble matter in the nine leading brands of butter salts is negligible.

Rate of Solution of Butter Salts.—Aside from solubility proper, the rate of solution is important. A high rate of solution

Table 39.—Rate of Solution of Butter Salts
Percentage of Salt in Solution in Seconds

Rate of Solution Seconds	Brands of Cube and Flake Salts								
	No. 1 Cube	No. 2 Flake	No. 3 Flake	No. 4 Cube	No. 5 Flake	No. 6 Cube	No. 7 Cube	No. 8 Cube	No. 9 Cube
5	20.20	22.40	21.28	20.82	19.75	21.03	20.04	21.14	20.82
10	23.72	24.33	23.63	23.66	22.95	23.76	23.38	23.84	23.67
15	24.67	25.22	24.80	24.72	24.32	24.99	24.59	24.87	24.74
20	25.35	25.60	25.24	25.30	24.94	25.54	25.22	25.39	25.27
25	25.62	25.87	25.45	25.73	25.45	25.91	25.68	25.70	25.72
30	25.75	25.97	25.67	25.71	25.52	26.07	25.94	25.92	25.90
40	26.10	26.19	25.96	25.86	25.98	26.34	26.22	26.09	26.14
60	26.25	26.32	26.19	26.17	26.26	26.35	26.43	26.24	26.31
90	26.33	26.39	26.29	26.31	26.22	26.51	26.47	26.30	26.38
120	26.35	26.43	26.34	26.40	26.48	26.37	26.54	26.32	26.40
180	26.38	26.43	26.36	26.44	26.47	26.51	26.55	26.34	26.40
240	26.30	26.42	26.37	26.44	26.54	26.66	26.56	26.33	26.39

facilitates the complete solution of the salt and intimate fusion between brine and water in the butter during the working process. This is necessary in order to avoid leakiness, grittiness and unevenness of color. The actual rate of solution of the different kinds of butter salts was determined by Hunziker et al, and is shown in Table 39.

Extraneous Matter in Butter Salts.—In order to be suitable for butter manufacture the salt should be free, or nearly so, from extraneous matter of any kind. Whatever foreign impurities that may be contained in the butter salt will reappear as foreign matter in the butter. There is considerable difference in the turbidity and color of brine and in amount of sediment that different brands of salt will show. A good butter salt should yield a clear and colorless brine and be as nearly as possible free from sediment. It is wisdom on the part of the buttermaker to occasionally make a sediment test on the salt he is using.

A very simple and convincing test is to dissolve about 25 lbs. of the salt in 10 gallons of water and pour the solution through a cotton pad filter using a standard milk strainer such as fits into the mouth of a 10 gallon can. A pad which shows only slight discoloration and is free from dark specks, indicates satisfactory freedom of the salt from objectionable extraneous matter. A badly discolored pad or a pad that shows a multitude of dark specks gives an idea of the amount of foreign matter that

Table 40.—Turbidity and Sediment of Brines from Different Brands of Salt (Hunziker et al).

Brand of Salt No.	Turbidity and Color of Brine		Insoluble Sediment	
	Turbidity Value*	Color of Solution	Sediment %	Appearance of Sediment
1	108	Gray, turbid	0.031	Gray brown
2	5	Colorless, clear	0.007	Light brown
3	5	Colorless, clear	0.004	Gray
4	60	Brown, turbid	0.032	Dark brown, specks
5	3	Colorless, clear	0.003	Light gray
6	40	Deep brown, turbid	0.024	Dark brown
7	12	Slight brown, turbid	0.011	Very dark brown
8	10	Slight brown, slightly turbid	0.006	Light brown
9	5	Colorless, clear	0.005	Black

*A.P.H.A. Standard Methods of Water Analysis (1925).

is added to each churning of butter with the salt. Such salt is unfit for use in butter manufacture.

Table 40 provides somewhat of an idea of the foreign matter contained in the different brands of butter salt. Much improvement has been made within recent years by the leading butter salt manufacturers in their efforts to protect their salt during manufacture against objectionable contamination with extraneous matter from corroded equipment and impure air.

Protection and Use of Butter Salt in the Creamery.—As far as the relation of the available high grade butter salts to flavor and keeping quality of butter is concerned, the really important factors are the care which the salt receives in the creamery and the manner in which it is used. Within the range of leading standard butter salts on the American market, the brand is relatively unimportant. In order to best guard against the possibility of any quality-damaging effect of the butter salt the following precautions are important:

Keep the butter salt in a dry place. It readily absorbs moisture. Even a small amount of moisture will cause it to appear damp, to lose its free-flowing property, and to lump and cake. Salt barrels or bags should not be allowed to be stored directly on the ground. The ground is always damp and during the thawing season it is wet. Store the salt barrels and salt sacks off the ground floor, in a clean dry room. Keep them away from rubbish and from material that gives off objectionable odors. Salt readily absorbs odors from vegetables, oil, kerosene, gasoline, exhaust of gasoline engine, etc. Make a tight-fitting cover for the remnant barrel, and keep this barrel covered as long as it contains salt. When first opening a new barrel, brush and wipe off the head to prevent exterior dust and other foreign matter to reach the salt. In the case of sacks, clean their outside before opening. Sift the salt before use. Salt lumps added to the butter dissolve slowly and tend to cause grittiness, sharp flavor and color defects. If stored where it will get very cold, keep a week's supply in a clean, dry place in the creamery during the cold weather. Cold, frozen salt dissolves slowly.

Freedom from a sharp, salty taste and grittiness requires complete solution of the salt and thorough incorporation of the brine during the working process. This is facilitated by having the butter at the proper firmness at the time the salt is added and work it to a fairly dry body. A soft bodied butter makes

proper salt incorporation difficult. High-salt butter requires more working than low-salt butter. Wetting the salt expedites its solution.

WORKING THE BUTTER

Purpose.—The fundamental purpose of working the butter is to completely dissolve, uniformly distribute and properly incorporate the salt, to accomplish as complete as possible a fusion between brine and water in butter, and to bring the granules of butter together into a compact mass for convenient handling and packing. Incidentally the working process further serves to expel buttermilk and to control the moisture content of butter. The working is an important part of butter manufacture, it is a science which requires knowledge, and it is above all an art that demands experience and judgment on the part of the operator, if uniformly satisfactory results are to be obtained.

Types of Butter Workers.—Butter is worked either with or without worker rolls. For either method numerous makes of butter workers are available.

Butter Workers with Worker Rolls.—In principle, the roll workers are of two types, namely, those which are independent of the churn, and in the use of which the granular butter is taken out of the churn, and those which are an integral part of the churn, known as combined churns and workers.

To the first group belong all the hand workers used in farm buttermaking, which consist of a bowl, tray or table on which the butter is worked with ladles or with a level worker, or by one or more revolving, corrugated rollers. To this group also belongs the mechanical table worker for factory use, consisting of a large, circular, rotating table with two revolving, corrugated worker rolls.

The combined churns and workers with rolls, now in use, are of three general types, namely, the long barrel churn with permanently installed worker, and doors in the side of the barrel, the short barrel churn with multiple pairs of rolls permanently installed near the periphery of the churn barrel and with door at one end, and the short barrel churn with twin worker rolls mounted on a separate carriage with gear connections, which enters the rolls through the open churn end at the time of working.

In the first type of combined churn and worker with worker rolls, the butter worker consists of one, two or four rollers, running lengthwise either at the center or near the periphery of the churn. These worker rolls have steel shafts at each end which run in bearings in the ends of the churn barrel, with power at-

Fig. 70. Victor churn (4 worker rolls)
Courtesy of Creamery Package Mfg. Company

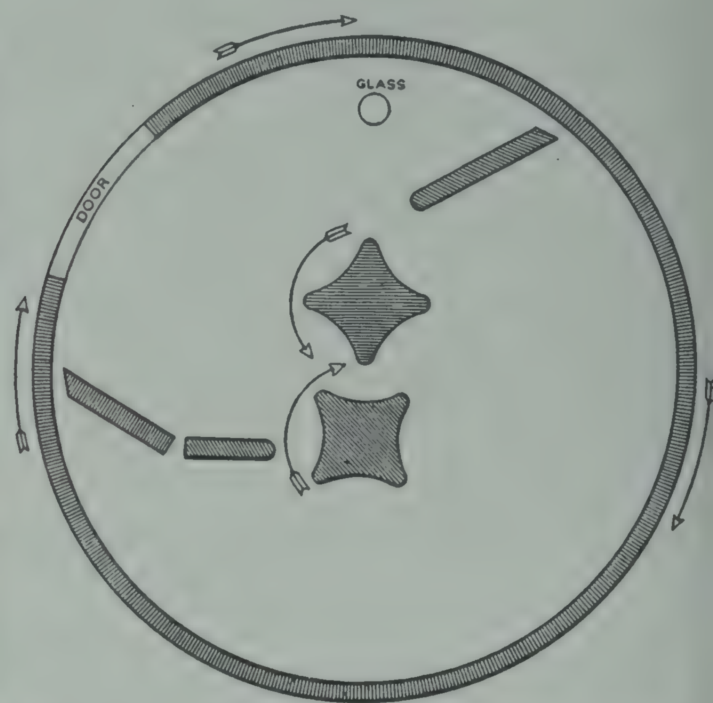


Fig. 71. Model "H" churn (2 worker rolls)
Courtesy of Creamery Package Mfg. Company

tachment at one or both ends on the outside of the churn barrel. In this type of churn the finished butter is brought up on a shelf at the doors and removed by hand, or it may be automatically dumped into a carrier trough placed underneath the churn. Representative churns of this type are the Perfection, Dreadnaught, Victor, Wizard.

In the second type of combined churn and worker with worker rolls, the finished butter is unloaded by dropping from the worker rolls into a portable tray pushed in through the open churn end. The tray is mounted on a wheel truck. The Supersimplex of Australia, the Silkeborg of Denmark and the Astra of Germany are representatives of this type.

In the third type of combined churn and butter worker with worker rolls the butter is worked through twin rolls that are pushed into the churn. For unloading the working gear is disengaged and the butter drops into a tray placed on top of the worker roll carriage. The Simplex churn is representative of this type.

Fig. 72. Dreadnaught churn (1 worker roll)
Courtesy of Cherry-Burrell Corporation

In churns with one worker roll, such as the Perfection and Dreadnaught, the worker roll works the butter against a shelf, the butter being squeezed through the space between worker roll and shelf. In all other roller churns, the butter is kneaded between twin rollers. In all churns excepting the Wizard, the churn revolves while the rollers are rotating. Some of the combined churns and workers of European manufacture provide for multiple speed of the worker rolls. In addition to the normal working speed, they permit of working at very low speed (snail gear), which is used at the conclusion of the working process proper, to accomplish maximum fineness of moisture dispersion without danger of developing excessive stickiness.

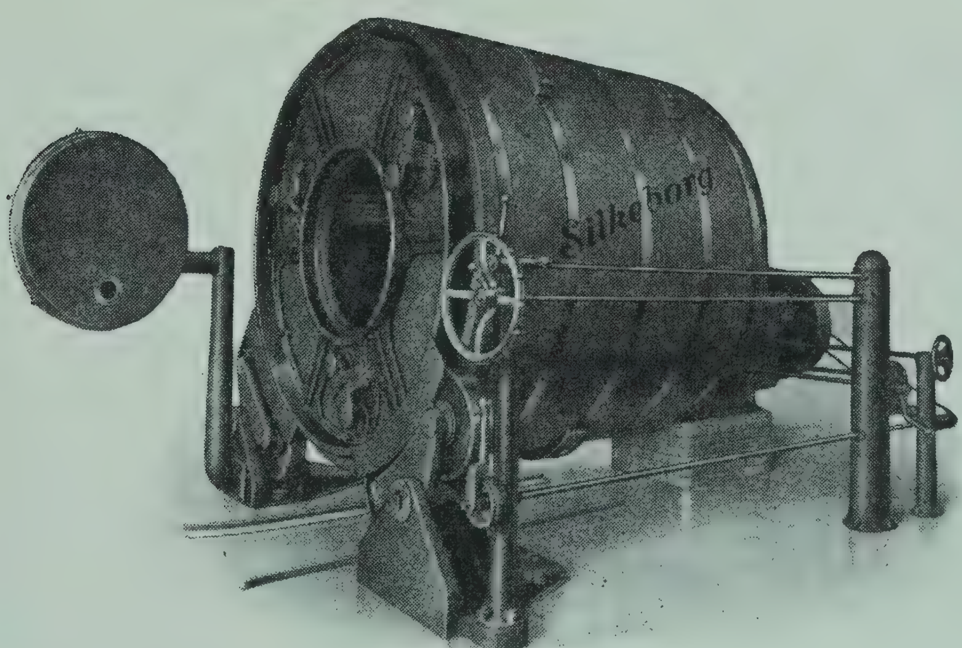


Fig. 73. Silkeborg churn (3 sets of twin worker rolls)
Courtesy of Silkeborg Maskinfabrik

Mechanical Condition of Worker Rolls.—In order for the churns with worker rolls to work all the butter alike, to distribute the moisture and salt evenly and to insure uniformity of

color throughout the churning, the churn must rest level, the worker rolls must be set correctly, must be taut and free from excessive slack, and the shelves must be rigid. The distance between twin rolls or between single roll and shelf must be the same over their entire length, the twin rolls must be properly nested and sufficiently free from slack, to insure permanency of their nested position while in operation. Improperly set, mal-adjusted, loose and slipping worker rolls cause uneven working and the appearance of mottles in butter.

Loseness or slipping of the worker rolls indicates a faulty mechanical condition of the churn. In some cases the trouble is due to the steel shafts having worked loose in the ends of the worker roll. In others the roller shaft may be slipping in the gear wheel, due to a worn key, or the cause may lie in an excessively worn condition of the cogs in some of the gear wheels. The proper working of the butter requires unrelenting attention to the mechanical up-keep of shelves, worker rolls and churn gears.

Overloading the Worker Rolls.—When the amount of butter in the churn is excessive, the working efficiency suffers, resulting in incomplete and uneven working, uneven distribution of moisture and salt, incomplete incorporation of brine, and a tendency for the butter to develop streaks or mottles.

Overloading usually causes the butter to crowd toward the ends of the churn where the projecting bolt heads and recessed spy glasses augment its tendency to stick to the end, and to be carried around with the revolving churn, without going through the workers. Likewise, some of the butter in excess of the working capacity of the rolls will drop over the outside of the rolls and will thus miss the working action. In either case there is incomplete working of some of the butter, jeopardizing uniformity of composition and evenness in color.

Other Conditions that Affect the Efficiency of the Worker Rolls.—Width of worker rolls, distance between the rolls, speed of the rolls and relative firmness of the butter, influence the working capacity and efficiency.

Wide diameter rolls can handle more butter without spilling a portion over the outside or crowding the ends, than narrow rolls. Worker rolls with deep corrugations and with a considerable space between rolls will work more butter than worker

rolls with shallow corrugations and set close together. Wide spacing between rolls, however, does not permit of efficient working in the case of small churnings. High speed workers will work more butter than low speed workers. Excessive speed, however, makes for rapid moisture incorporation and stickiness. Low speed retards moisture incorporation and in the case of hard butter may cause excessive expulsion of moisture. Low speed, however, assists in the accomplishment of fine moisture dispersion, when applied after the butter has been worked sufficiently at normal speed. Such butter can be worked at low speed without much danger of developing stickiness. Hard butter does not go through the worker rolls as rapidly as soft butter. In fact, in the case of hard butter, it may require many revolutions of the churn before all the butter will pass through the rolls. Excessively soft butter, on the other hand, does not offer enough resistance to break up the moisture droplets into fine units. It results in incomplete moisture dispersion and a leaky texture.

Rolless Combined Churns and Workers.—In the conventional roll churn the working principle is provided by the mechanical force of the revolving worker rolls. In the rolless churn the force of gravity, assisted by either the particular shape of

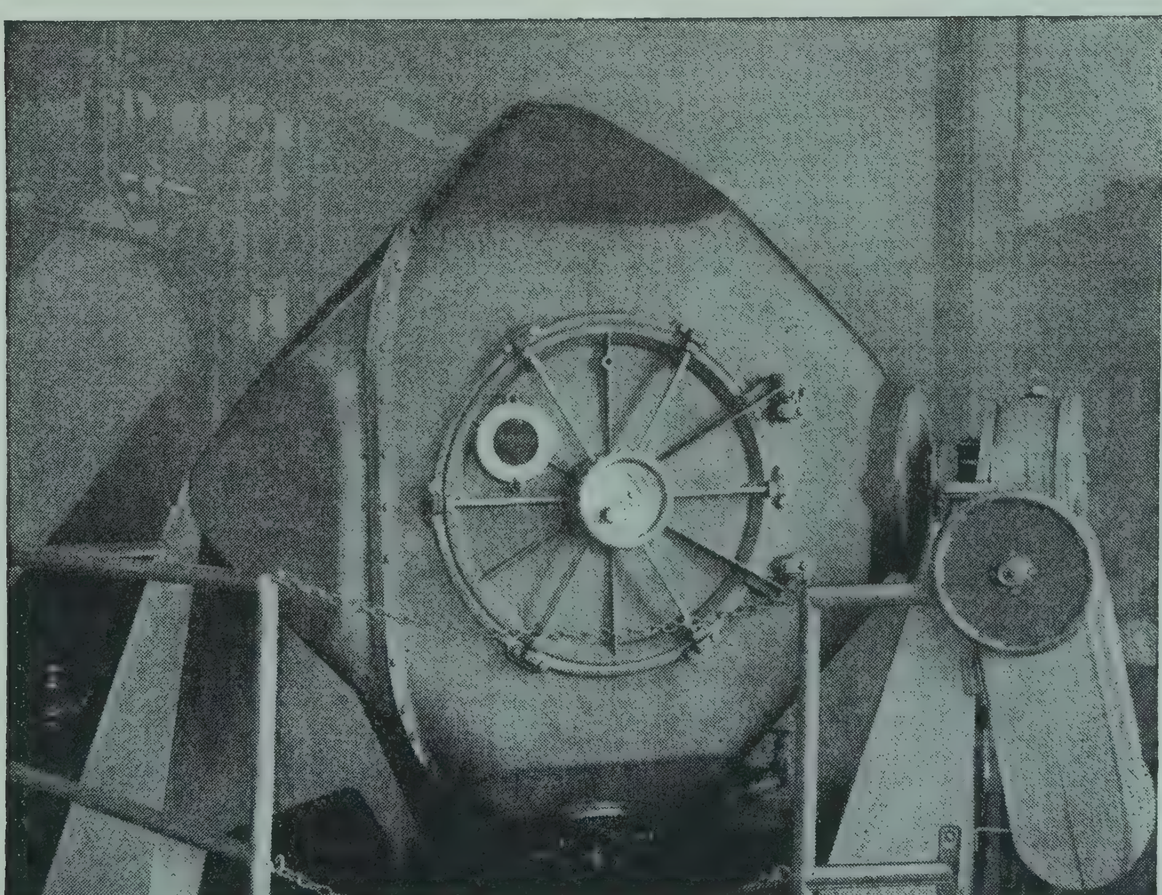


Fig. 74. Challenge (Jensen) No-Roll, all-metal churn and butter worker
Courtesy of Jensen Machinery Co.

the churn drum or its special internal arrangement of shelves, supplies the working principle and the butter itself is performing the kneading.

The construction of churns without worker rolls, for the express and specific dual purpose of churning the cream and working the butter, appears to be of comparatively recent date, beginning apparently with the advent of the Challenge No-Roll, All-Metal Churn invented in 1933 by C. L. Mitchel and E. L. Wetmore of the Challenge Cream and Butter Association of Los Angeles, California.

The practice of working butter in churn drums without mechanical worker, however, is not new. It was in use in some creameries before the advent and general use of the combined churn and worker with mechanical worker rolls. Rectangular box churns such as the old Chautauqua churn, were then preferred for this purpose. In these churns the force of concussion was depended upon exclusively for working, and for the distribution and incorporation of moisture. In the then prevailing absence of practical factory tests for the accurate determination of the composition of butter, but little attention was paid to moisture control and there is practically no dependable information available of the working efficiency of the rolless box churn of those days.

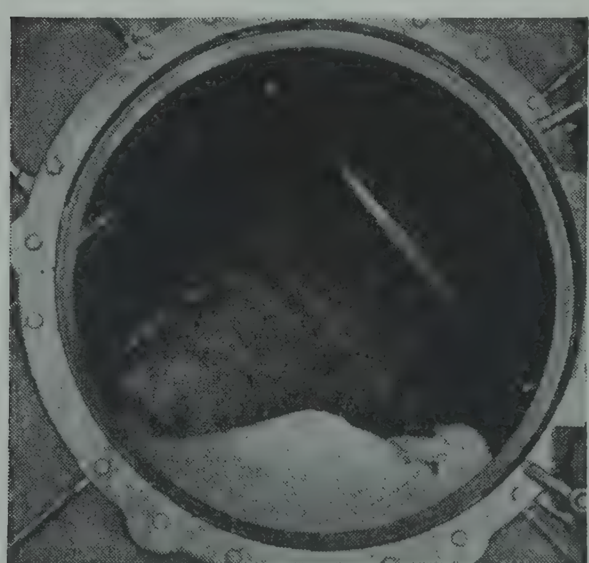


Fig. 75. Showing finished butter in churn of Fig. 74
Courtesy of Jensen Machinery Co.

The Rolless combined churns and workers that are in successful use today are of more recent design. They are the result of extensive experimental study, on the part of the churn manufacturer, of the factors involved in proper working that assures uniform control and distribution of moisture and salt, efficient incorporation of moisture, and a satisfactory texture of butter. As the result of these efforts numerous makes of rolless churns are now available to the industry, in which the butter is subjected to such a succession of flattening, folding, reforming and kneading as to accomplish a very high degree of working efficiency.

The modern rolless churn is an American invention. At

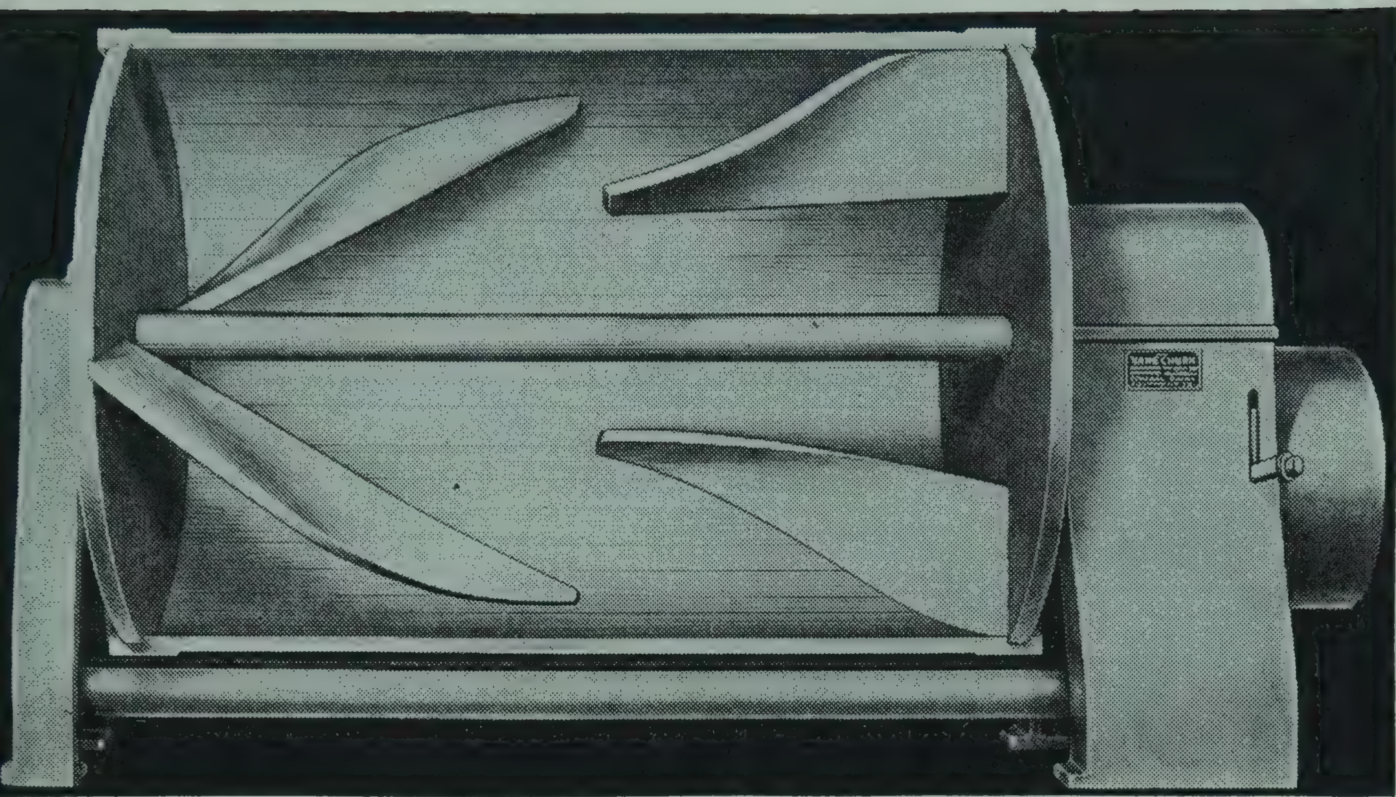


Fig. 76. Vane No-Roll churn and butter worker
Courtesy of General Dairy Equipment Co.

this time (1940) the rolless worker principle is represented in the United States by five different makes of combined churn and worker; namely, the Challenge All-Metal Churn of the Jensen Machinery Co., Bloomfield, N. J., the Crano Spiral Churn of the Crane Co., St. Paul, Minn., the Vane Churn of the General Dairy Equipment Co., Minneapolis, Minn., the C. P. Sanitary No-Roll Churn of the Creamery Package Mfg. Co., Chicago, Ill., and the Sani-Drum Rolless Churn of the

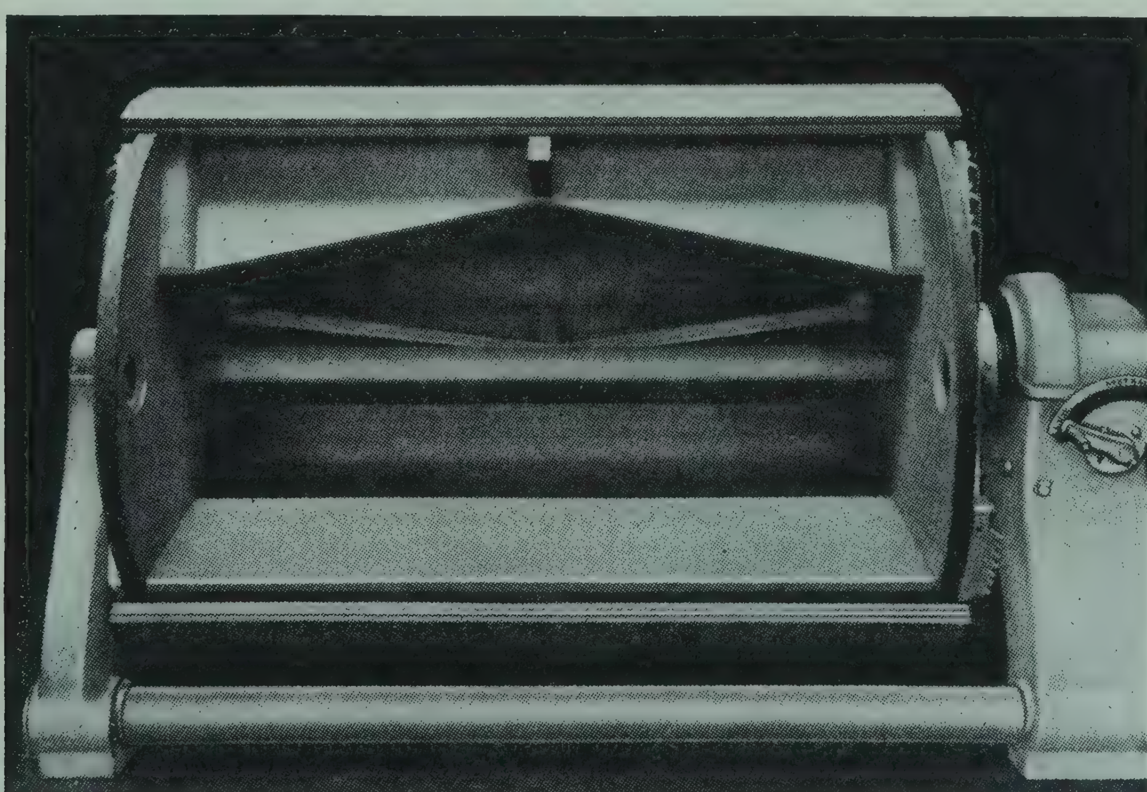


Fig. 77. Sani-Drum Rolless churn and butter worker
Courtesy of Cherry-Burrell Corporation

Cherry-Burrell Corporation, Cedar Rapids, Iowa. The accompanying illustrations may serve to show the internal arrangement of some of these churns.

The Challenge No-Roll All-Metal Churn was the first modern rolless churn supplied to the industry in the United States.

Fig. 78. Sanitary No-Roll churn and butter worker
Courtesy of Creamery Package Mfg. Company

It has the further distinction that it is the only all-metal churn available and in successful use. This churn is fabricated from cast aluminum alloy and its interior surface is sufficiently porous to retain the necessary water film that eliminates the tendency of butter to stick to the metal. It is of cubical shape, with rounded corners and is mounted on trunnions at diagonal corners. The six peripheral corners thereby revolve through two different vertical planes, which gives the butter a sidewise movement. The churning, as well as the working, thus is a combination of both rotary and of horizontal motion augmenting the kneading action and favoring optimum evenness of distribution of moisture and salt. The churn

Fig. 79. Cross section of churn shown in Fig. 78
Courtesy of Creamery Package Mfg. Company

has ribs on the inside, which strengthen it, and tend to decrease the time required for churning and working. The other modern American rolless churns and butter workers listed above have retained the conventional wooden drum (barrel), and the working percussion is made possible by the arrangement and slope of their internal shelves.

In Europe, the Silkeborg Maskinfabrik of Denmark have recently also placed upon the market a rolless churn and butter-worker. As shown in the accompanying illustration, this churn is of cube shape. According to advice from its manufacturers this churn is made after an old American churn pattern (of the previous century), the principle alteration being that the two

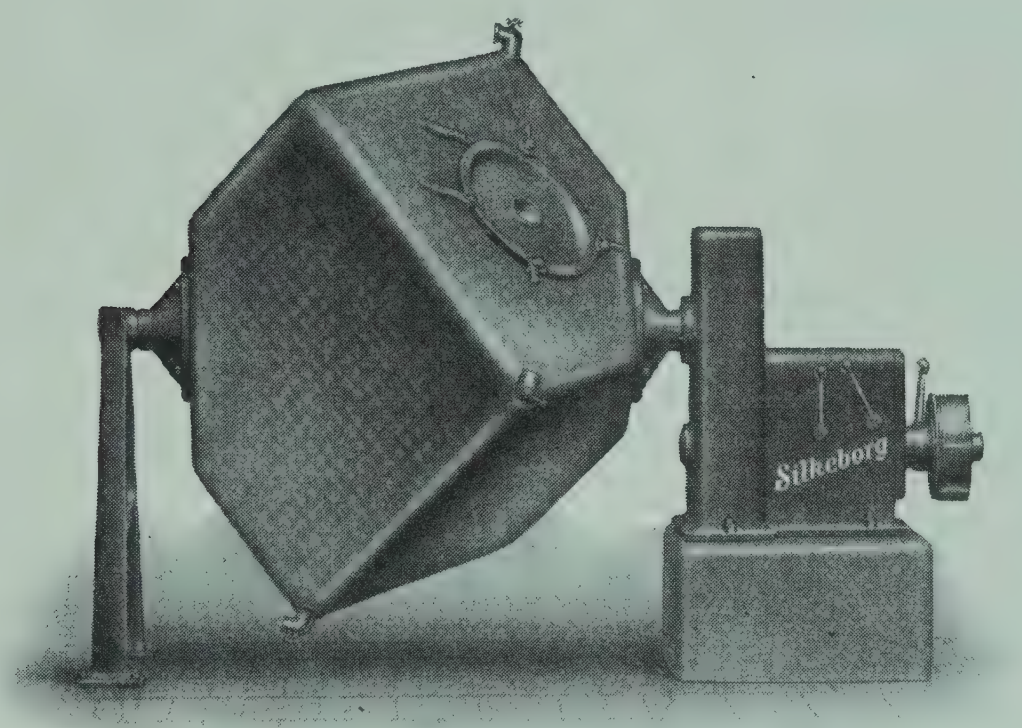


Fig. 80. Silkeborg all-metal, roller-less churn and butter worker
Courtesy of Silkeborg Maskinfabrik

axial corners have been cut away in order to shorten the machine and to decrease its space requirements. The box of the Silkeborg churn is constructed of stainless steel and the multiple speed gears of milled steel.

Performance of Rolless Combined Churn and Worker.—Accurate comparative tests between the rolless and the roller churn are as yet too limited to justify final conclusions. The work of Hunziker, Behlmer, Cordes, and Harris,[23] using split churnings for comparative tests between one make of rolless churn and one roller churn, demonstrated the superiority of the rolless churn from the sanitary standpoint and with regard to working flexibility.

Sanitary Advantages of Rolless Churn.—The results of bacteriological analysis of the butter were consistently in favor of the rolless churn. The total bacteria count was slightly but persistently lower and the yeast and mold count was much lower in butter from the rolless churn. This is as might be expected, as with the worker rolls out of the way, some of the most prolific potential bacterial breeding places are eliminated and all parts of the interior of the churn are vastly more accessible to cleaning, making it comparatively easy to keep the rolless churn in sanitary condition. In the case of the Jensen No-Roll All-Metal Churn, which is constructed of aluminum throughout, the sanitary advantage is particularly obvious.

Working Flexibility of Rolless Churn.—The use of the rolless churn also demonstrated its greater working flexibility. It works small churnings equally satisfactorily as large churnings. It eliminates moisture control difficulties that are inevitable in the case of small churnings worked in the roller churn. This should prove particularly helpful to the small creamery, with churnings of irregular size.

In addition, the rolless churn proved surprisingly efficient in reworking high moisture churnings. It eliminates excessive moisture from properly chilled butter fully as readily as the roller churn. Using the rolless churn for reworking, obviously also largely eliminates excessive strain on the churn gears.

Moisture Incorporation Efficiency of Rolless Churn.—Available experimental results on moisture dispersion and on body of butter are too limited in scope to demonstrate conclusively the possibilities and limitations of the rolless churn in these respects. Such comparative tests as have been made, however, suggest that moisture and salt distribution in the rolless churn is equal to that in the roller churn and there is no noticeable difference in the tendency toward stickiness or leakiness between the two churns. These indications are likewise supported by commercial experience. In the experiments cited[23] the butter from the rolless churn showed a very slight bead of moisture on the trier and suffered somewhat greater loss of moisture in the cooler and in the Doering cutter. These facts suggest the possibility of somewhat lesser thoroughness of moisture incorporation, the correction of which may be largely a matter of proper adjustment of speed of churn and of number of revolutions

worked. The experiments of Hunziker and co-workers further showed that the rolless churn shortened the churning time, averaging a saving of six minutes per churning. The buttermilk test averaged the same for both types of churns.

The above results refer to experiments with the wooden drum rolless churn. The Danish Experiment Station[38,39] at Hillerod, Denmark, likewise reported satisfactory moisture control and uniform distribution of moisture and salt, as well as relatively low to normal fat losses in the buttermilk, with the stainless steel cubical no-roll churn.

Amount of Working.—Regardless of type of equipment, or method of working, the working should continue until the butter has a compact body, a closely knit grain, and a tough waxy texture. Consistent with proper moisture control, butter has been sufficiently worked when it breaks with a long ragged edge upon slashing a ladle through it quickly, and when a cross cut shows complete absence of pockets of free drops of water and of moisture beads visible to the naked eye. The body should be dry and the color densely opaque. Insufficient working usually yields a loosely knit texture, with large visible aggregates of water and a deep yellow, translucent color. Such butter tends to be leaky and may develop mottles upon standing.

Overworking of firm, hard butter granules tends to yield a short grain, salvy body, becoming brittle in the cooler. In the case of winter cream, overworking aggravates the sticky-crumbly defect. Overworking of soft butter granules in churns equipped with mechanical worker rolls, lends the butter a greasy character. Firm butter requires and will stand more working than soft butter, but the working should not be carried to the point where the butter sticks to the worker rolls.

The most critical butter markets demand a closely knit, firm, dry body and most of the great butter exporting countries, such as Denmark, Canada, Australia, and New Zealand have found it necessary to, and do produce butter of such body and texture in order to satisfy the world market. In the American markets too, the trend is toward giving preference to a closely knit compact body, free from the tendency toward leakiness. Such butter has the further advantage of holding up in weight and avoiding heavy loss due to leakage after manufacture, when in transit, while running through the butter cutter, or when stored.

Effect of Working on Distribution of Moisture in Butter.—The moisture associated with the washed butter granules is present in two forms. A portion of this water consists as exceedingly minute droplets of buttermilk enmeshed and permanently held within the butter granules. The water so held constitutes approximately 8 to 9% of the weight of the butter. The remaining moisture consists of the wash water that adheres to the surfaces of and that is entrained between the butter granules. This water is present in drops and larger aggregates of free moisture. It is only loosely held in the unworked butter.

At the beginning of the working process much of the loosely held water is expelled. During the first few revolutions of working the moisture content of the butter decreases. Under normal conditions it may drop to about 12 to 13%. The decrease in moisture content at this point is more pronounced in salted than in unsalted butter, because the salt draws the loosely held water droplets together into larger drops, which facilitate expulsion.

As the working progresses the butter loses it granular state and becomes less friable and more plastic. When this point is reached, further working causes the butter to "pick up" free water or brine from the churn and its moisture begins to increase again. This increase continues, and the amount of water that the butter is capable of assimilating in the working process depends on the firmness of the butter, the speed of the worker rolls and on the amount of free water in the churn.

In the case of abnormally soft butter, excessively high speed of workers and an ample supply of free water, it is possible to "beat" enough water into the butter to raise its moisture content to over 75%. With butter of normal firmness and working at normal speed, the saturation point is usually reached at a moisture content of approximately 20 to 25%, and additional working in the presence of water will not materially raise the moisture content further. The desired effect of working is or should be to produce the finest possible dispersion of the water or brine that is incorporated in the butter, without giving the butter a sticky character.

Danish Experiments with the Victoria-Kubus Churn.—A further modification of the method of working was recently experimented with by the Danish Dairy Experiment Station at

Hillerod, Denmark.[38,39] The churn used for these experiments was a no-roll cubical stainless steel churn, the Victoria-Kubus churn, designed and constructed by Paasch and Larsen. The churn has no internal contrivances. The inside walls are roughened by sand blasting. The corners are rounded to prevent butter from sticking in the corners, and are equipped with buttermilk gates to facilitate expulsion of the buttermilk. The churn door has an air-tight seal and the churn is equipped with a lever-controlled butter outlet.

In the experiments above referred to the butter was worked at a temperature sufficiently high to give it a soft, emulsified consistency at the completion of the working process. For unloading the churn, the lever-controlled butter outlet was opened and the butter in this soft condition was forced out under a

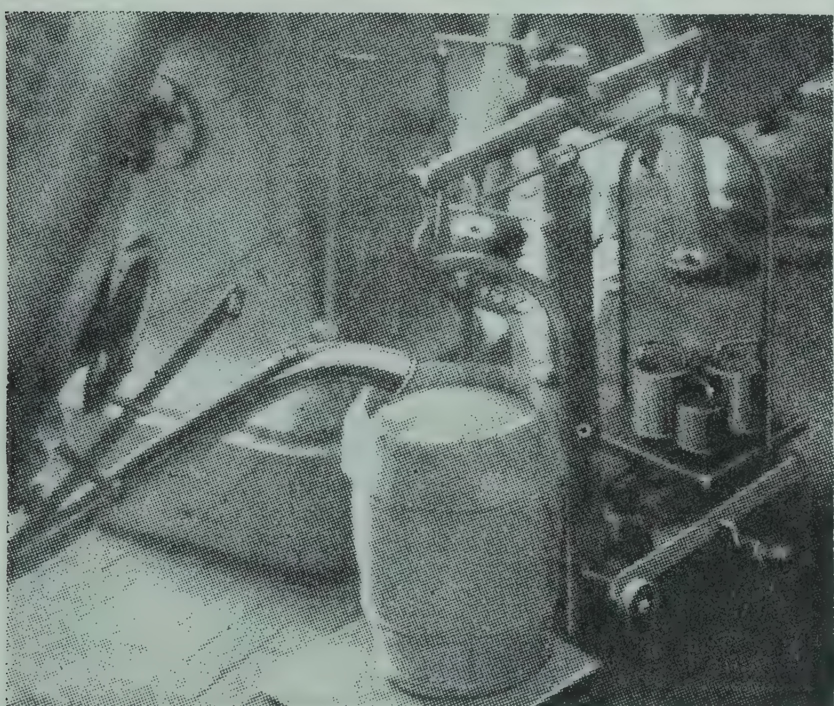


Fig. 80¼. Unloading Victoria-Kubus churn
From 24th Danish Expt. Sta. Report, 1939

pressure of about 3 to 5 pounds of compressed air. The butter is thus transferred automatically direct from churn to the final package, in this case the firkin, resting on platform scales. Tests of the butter for firmness at the end of 14 days, showed that the firmness increased with increasing working temperature. The temperature range at which the butter was worked, that yielded the best quality, was 18 to 22° C (64.4 to 71.6° F.). This temperature was attained by the end of the working process, by spraying the churn on the outside with warm water suitably tempered, the churn revolving and the butter being worked while spraying the churn.

Preliminary moisture tests were made as soon as the butter had become sufficiently soft to stick to the sides. Warm water was added for raising the moisture content to the desired point, after which the working was continued and completed. Moisture dispersion was reported uniform and complete and moisture control efficient. The investigators further recommended to produce unwashed butter only with this equipment and process due to the special properties of this churn. The results of this method of working depend much on the proper correlation of such factors as temperature of butter at working time, speed of churn, and duration of working period. The method is as yet in the experimental stage.

MOISTURE CONTROL

Importance of Standardizing Conditions in Manufacture.—The foundation of dependable moisture control lies in so adjusting conditions of manufacture as to have in the churn, at the time the final working begins, just enough total water to yield the desired per cent moisture in the finished butter, when all the free water has been taken up by the butter. It is then possible to work the butter to a dry body without danger of exceeding the moisture limit.

It is especially uniformity of firmness of the butter granules, as controlled by the proper adjustment of the cooling temperature of the cream and the temperature of the wash water to seasonal variations in the composition of the butter fat, that is helpful in moisture control; because the degree of firmness determines the readiness with which the butter drains, the amount of water in the butter at the beginning of the working process, and its ability to take up free water during working.

Importance of Accurate Knowledge of Pounds Butter Fat in Churn and Per Cent Moisture in Unfinished Butter.—In order to know how much water to add to attain the desired per cent moisture in the finished butter, there is need of accurate determination of the pounds of fat and the moisture present in the churn. This means accurate weighing or measuring of the cream, representative samples for the cream test and correct tests.

In the one-churning creamery the exact pounds of cream in the churn are readily derived from the daily cream receipt sheet.

In creameries with larger volume and with vats holding more than one churning, the proper use of an accurately calibrated measuring stick usually yields fairly dependable results. Makeshift measuring sticks, carelessly used, however, may easily cause errors amounting to 100 lbs. of cream or more. The most dependable means of determining the correct weight of cream in the churn is to actually weigh the cream into the churn. This may be done by the installation of a tank on scales, sufficiently large to weigh a full size churning, and preferably elevated to empty the weighed cream into the churn by gravity. The weight of the cream may also be determined by the use of a properly functioning cream gauge attached to the front of each vat. Some of the cream gauges available, however, have not proved reliable. Unless efficiently supervised the average cream gauge is prone to become objectionable also from the sanitary standpoint.

The testing of the cream must be done accurately. This means care in securing a truly representative sample from the cream in the vat. This requires vigorous agitation to make sure that the richer cream near the surface has been thoroughly mixed back into the body of the cream. The sample should be taken with a long-handle dipper, pushed well down into the cream. The need of accuracy in making the cream test is obvious.

Finally, and very important, the per cent of moisture present in the butter must be determined at the time moisture control commences. This initial moisture test must be accurate, for it provides the basis for the calculation of the amount of added water required to attain the desired content in the finished butter. Unworked butter does not yield uniformly representative samples. Moisture distribution in the granular butter is seldom uniform. Moisture tests made from different samples of the same churning of unworked butter often vary widely and are unreliable. The usual practice is to work the butter to a fairly dry body after salting and before the first moisture test is made. At the time of the first moisture test there should be practically no free water or brine in the churn. For the sample, portions from different parts of the churn should be taken and the composite sample carefully tested for moisture.

Some buttermakers prefer to prework the butter to a fairly dry body and take the sample for the initial moisture test before

the salt is added. This permits of adding the maximum amount of water at the time of salting; which makes for ready solution of the salt and facilitates complete fusion of brine and water and uniform distribution of the salt throughout the mass of the butter. This method has the further advantage, that in the absence of salt at the time the sample for the first moisture test is taken, the moisture droplets are more uniformly fine, large aggregates and loose moisture are negligible, and the tendency for securing a representative sample is enhanced.

Calculating the Amount of Water to Add.—This first moisture test furnishes the basis for calculating the pounds of water that must be added to bring the moisture in the finished butter up to the desired percentage. The calculation may be made with mathematical accuracy by the use of the theoretical formula given below, or approximately, by the use of an arbitrary factor.

Calculation by Use of Arbitrary Factor.—Multiply the difference between the first moisture test and the per cent moisture desired in the finished butter by the factor 1.5 for each 100 lbs. of fat in the churn. The result is the pounds of water that must be added.

The arbitrary factor "1.5" represents the ratio of churn yield on the basis of a 25% overrun, times the corrective factor "1.2" (i.e., $1.25 \times 1.2 = 1.5$). The corrective factor "1.2" is an approximation of the ratio of the water required as figured by the mathematical formula, to that as figured by multiplying the pounds of finished butter by the difference between moisture present and moisture desired.

Example:

720 lbs. fat in churn.
Moisture desired in finished butter is 17.2%.
First moisture test is 15.2%.
How much water must be added?

Answer:

$17.2 - 15.2 = 2.0\%$ moisture to be raised.

$$\frac{2 \times 1.5 \times 720}{100} = 21.6 \text{ lbs. of water must be added.}$$

Calculation by Use of Mathematical Formula.—In order to determine the pounds of water necessary to add to bring the moisture in the finished butter up to the desired percentage

with mathematical accuracy, the following theoretical formula may be used. This formula gives the pounds of water present in the finished butter of the desired moisture content, and the pounds of water present in the butter at the time of the first moisture test. The difference is the pounds of water that must be added:

1.) % M.D. $\times$ B.F. $\times$ yield = lbs. water desired in finished butter.

2.) $\left[(\text{B.F.} + \text{curd} + \text{salt}) \times \frac{100}{100\text{-M.P.}}\right]$
— (B.F. + curd + salt) = lbs. of water present in butter at time of first moisture test.

3.) M.D. — M.P. = lbs. of water to add.

M.D. = Moisture desired in finished butter.
M.P. = Moisture present as per first moisture test.
B.F. = lbs. butter fat in churn minus fat lost in buttermilk.
Yield = Churn yield 1.25.

Example 1: (Salt added before first moisture test).

720 lbs. fat in churn (30% cream).
Buttermilk test 0.6%.
Finished butter contains 0.8% curd; 2.0% salt.
Moisture desired 17.2%.
Moisture present 15.2%.
Assumed churn yield 1.25.
How much water must be added to bring the moisture in the finished butter up to 17.2%?

Answer:

% fat lost in buttermilk of total fat churned =

$$\frac{[100 - (1.2 \times 30)] \times 0.6}{30} = 1.28\%$$

Lbs. fat lost $\frac{720 \times 1.28}{100} = 9.216$ lbs.

Fat available for butter 720 — 9.216 = 710,784 lbs.

1.) .172 $\times$ 710.784 $\times$ 1.25 = 152.82 lbs. water in finished butter.
.008 $\times$ 710,784 $\times$ 1.25 = 7.10 lbs. curd.
.020 $\times$ 710.784 $\times$ 1.25 = 17.76 lbs. salt.

2.) $\left[(710.784 + 7.10 + 17.76) \times \frac{100}{100 - 15.2}\right]$
— (710.78 + 7.10 + 17.76) =
131.82 lbs. water present (initial moisture test).

3.) 152.82 — 131.82 = 21.00 lbs. water to add.

Proof:

lbs. finished butter $710.78 \times 1.25 = 888.475$ lbs.

Lbs. moisture present at first test	=	131.82 lbs.
Lbs. water added	=	21.00 lbs.
Total moisture in finished butter	=	152.82 lbs.

% Moisture in finished butter $\frac{152.82}{888.475} \times 100 = 17.20\%$

Example 2: (Salt added after first moisture test).

Calculations are the same as in "Example 1," except that salt figures are omitted in formula "(2)" that gives the lbs. of water present. Formula "(2)" therefore, would read as follows:

$$2.)\left[(\text{B.F.} + \text{curd}) \times \frac{100}{100 - \text{M.P.}}\right] - (\text{B.F.} + \text{curd}) =$$

lbs. water present.

The above mathematical formula determines accurately the amount of water to add to bring the moisture in the finished butter to the desired percentage. It is applicable to salted and to unsalted butter. Its accuracy obviously depends on the degree of mathematical precision of operations in manufacture.

Comparison of the above results between the mathematical formula and the use of the factor, shows a discrepancy of 0.6 lbs. of added water for a churning of 888 lbs. of butter. Theoretically this would cause an error of 0.0675% in moisture content. In the above example the moisture had to be raised from 15.2 to 17.2% or 2%. A larger raise would increase the discrepancy while a smaller difference would decrease it. The error would also increase slightly with increasing salt content.

The discrepancy in amount of water to be added, between the mathematical formula and the use of the factor "1.5" is not great. The results from the use of the factor in commercial butter manufacture have proved consistently dependable. The mathematical formula is obviously too cumbersome and its use too time-consuming to be suitable for routine use by the practical buttermaker. The "factor" method of calculation, however, by reason of its simplicity and rapidity, and because of its relative accuracy, has been a real help to the busy buttermaker in his moisture control work.

Slide Rule for Moisture Control Calculations.—A handy slide rule for use in moisture control, designated the "C.P. But-

ter Compo-Guide," illustrated in "Fig. 80½," was designed by Godfrey.[40] Its calculations are based on a composition of 80.5% fat, 16.5% moisture, 1% curd, and 2% salt. For butter with this composition, and providing that the pounds of fat in the churn and the moisture shortage are accurately known, the Godfrey

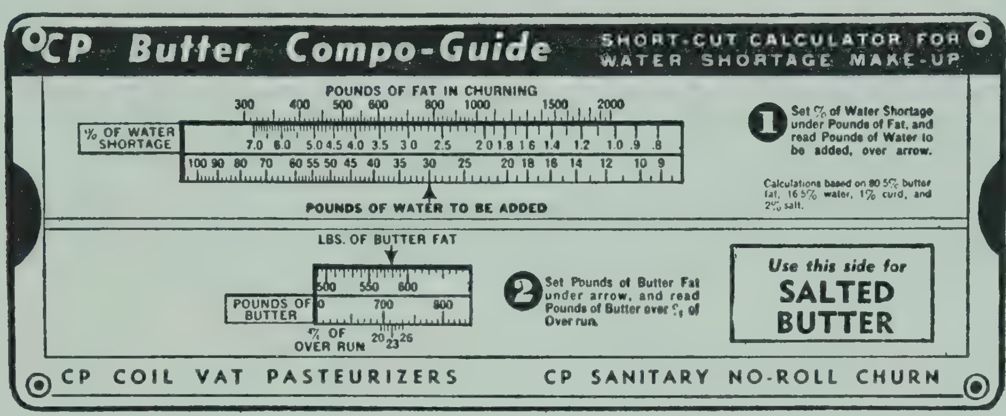


Fig. 80½. C. P. Butter Compo-Guide. Tells amount of water to add
Courtesy of Creamery Package Mfg. Company

slide rule yields values for pounds of water to add, that are mathematically correct. For compositions deviating from the above, actual mathematical accuracy should not be expected. However, within the usual normal range of variations of butter composition, the readings of the slide rule are sufficiently near correct for satisfactory moisture control. Within the limits of normal composition, therefore, this slide rule is applicable regardless of composition. Its use simplifies moisture control calculations, saves time, and diminishes the possibility of errors in figuring. It is arranged for use on the basis of either pounds of butter fat in the churn, or pounds of butter expected.

After the calculated amount of water has been added, the working should be continued until all the free water or brine has been taken up by the butter and the butter has been worked to a dry body. It is recommended that a second moisture test be made before the butter is removed from the churn, as a check on the accuracy of the moisture control work.

Effect of Working on Color of Butter.—Working tends to make butter appear lighter in color. Pure butter fat has a clear, translucent yellow color. The water droplets and also the air bubbles dispersed throughout the butter have the effect of hiding the color of the butter fat, because they deflect and throw back the rays of light, giving the butter a more opaque and lighter or creamy shade of yellow. This effect is greatest,

the finer the division and the greater the number of droplets and bubbles present. As the working process progresses, the water droplets decrease in size and increase in number, and this change is accomplished by a corresponding decrease in intensity of color. For details see Chapter XXIII under "Color Defects of Butter."

Dispersion of Moisture in Butter.—Boysen[3], Rahn and Boysen[4], and Rahn[29], made a most extensive systematic study of the moisture dispersion in butter. Their findings of the proportion of different size water droplets in unworked butter and in salted butter after working are shown in Table 41.

Table 41. Average Dispersion of Moisture in Butter

Size of Droplets Microns	Unsalted Unworked Butter		Salted Butter After Working	
	Number	Per Cent	Number	Per Cent
Less than 3	17,175,400	6.47	11,066,800	3.97
3-5	317,540	1.12	180,000	0.61
5-10	72,080	1.67	60,230	1.33
10-15	9,040	0.97	11,570	1.18
15-25	620	0.27	600	0.25
25-35	115	0.17	160	0.23
35-45	46	0.16	69	0.23
45-55	20	0.14	29	0.19
55-65	8.5	0.10	16	0.18
65-75	6.	0.11	12	0.22
75-85	2.5	0.07	6.5	0.17
85-95	2.5	0.10	5.1	0.19
Over 100	—	10.28	—	3.61
Total	17,600,000	21.63	11,300,000	12.36

Boysen's work further shows that working increases and salting decreases the number of small droplets. These findings harmonize with the earlier results of Hunziker and Hosman.[36] See also Figs. 81 to 92.

Effect of Working on Air Content of Butter.—Working increases the air content in butter. The presence of air in butter was first demonstrated by Rogers.[25] Pickerell and Guthrie[26] found the air content of butter to vary within wide limits (0.5 to 6.0%). Similar results were reported by Rahn and Mohr[27] who show a range of 0.97 to 8.38 cc. air per 100 grams of butter, averaging 4.2%.

All butter contains some air, regardless of the working process, because air is unavoidably incorporated in the butter

granules at the time of their formation during churning, as the result of the foam in the cream. The amount of additional air that is beaten into the butter during working has not been conclusively determined, but Rogers' work has definitely shown an increase in the air content by working.

The nature and amount of working influences air incorporation. Hunziker[28] showed that the butter may be increased four fold in volume by whipping it. Prolonged working, and high speed of worker rolls, cause increased air incorporation. It has been the author's further observation that creameries drawing their cream supply from territories where cottonseed products play a prominent role in the feed ration, find difficulty in packing standard butter packages such as 63 lb. tubs, with the full net weight of butter. The abnormally hard and gummy character of the butter made from such cream requires working much in excess of that normally suitable, and this in turn incorporates enough air in the butter to increase the volume of butter from about 1 to 3%.

Excessive working not only increases the air content of the butter, but it divides and disperses the incorporated air bubbles into much smaller particle size and larger numbers. The increase in number of these minute air bubbles has a similar effect on the color of the butter as the fine dispersion of the water droplets, resulting from intensive working. It functions in the direction of giving the butter a lighter color. It also exposes the butter fat to more air contact, the effect of which on quality is discussed in succeeding paragraphs.

Effect of Working on Flavor of Butter.—The amount of working within a rather wide normal range of revolutions has no appreciable effect on the flavor of the fresh butter. Overworking, on the other hand, tends to diminish the intensity of flavor.

The aromatic substances, whether desirable or objectionable, are localized largely in the serous portion. In butter that is moderately worked, so that the grain is well preserved, the aromatic substances stand out prominently and are readily accessible to the palate and nose. In overworked butter, with an excessively broken-down grain and a dull, dry body, aroma and flavor are less pronounced and the butter gives the impression of a lifeless character. In the case of butter made

Size and Number of Water Droplets in Unsalted Butter at Different Stages of Working Process Magnified X 740

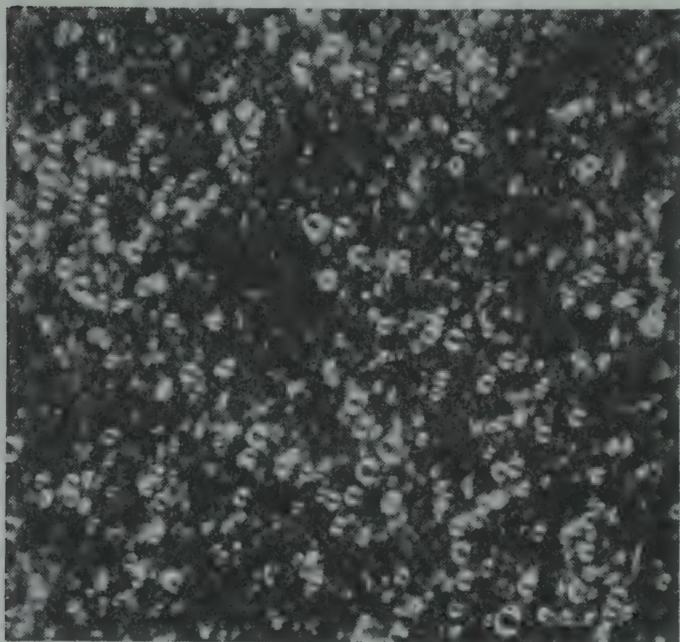


Fig. 81. Worked six revolutions no mottles

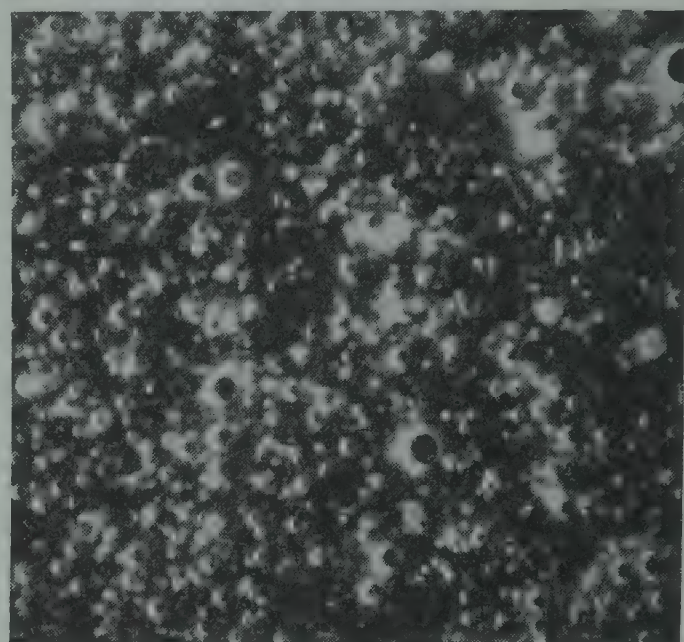


Fig. 82. Worked 12 revolutions no mottles

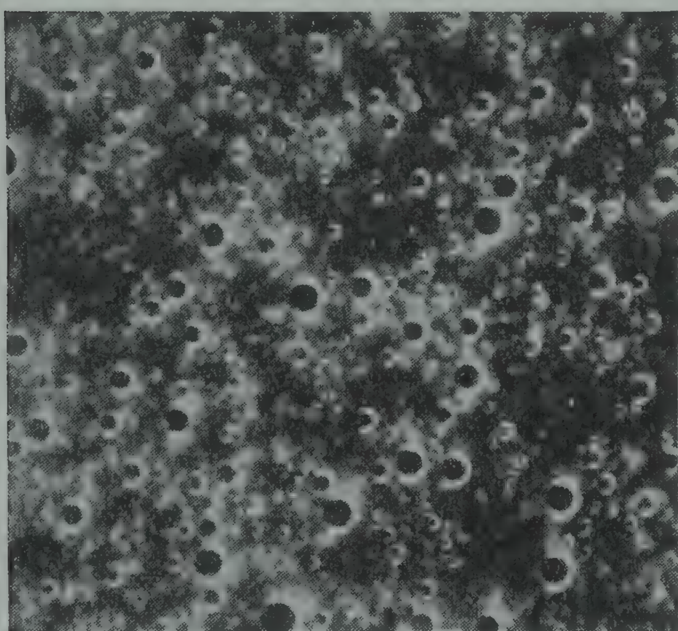


Fig. 83. Worked 18 revolutions no mottles

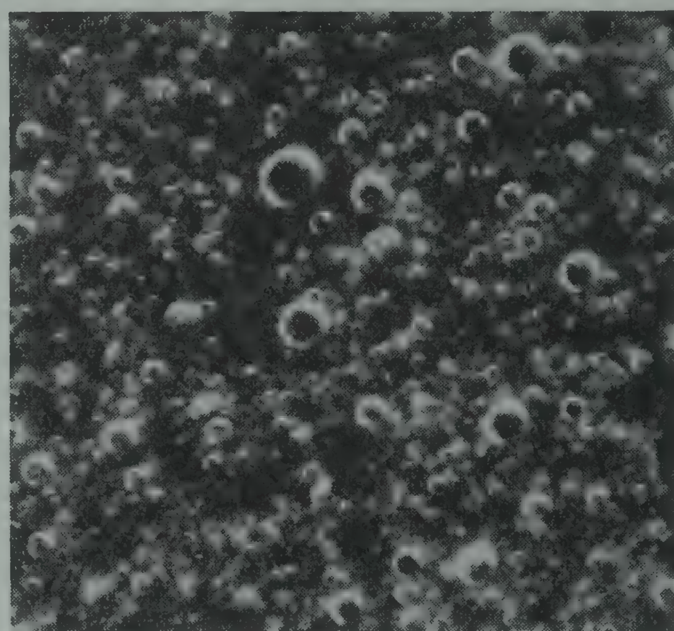


Fig. 84. Worked 26 revolutions no mottles

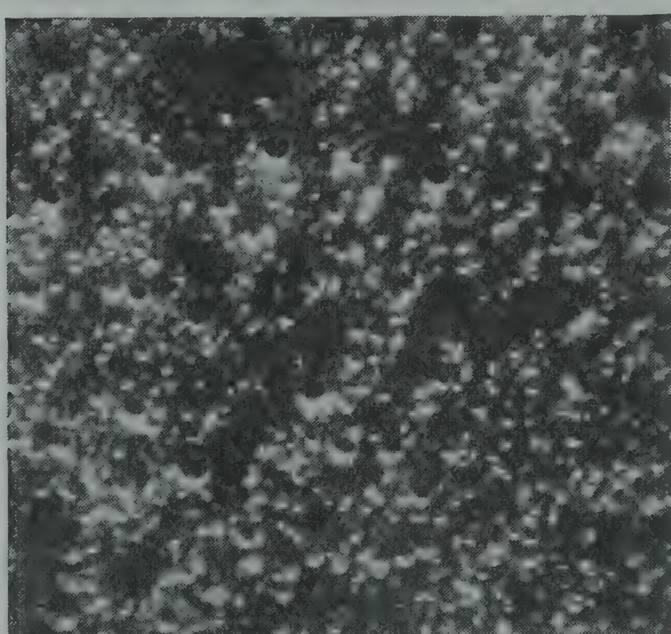


Fig. 85. Worked 34 revolutions no mottles

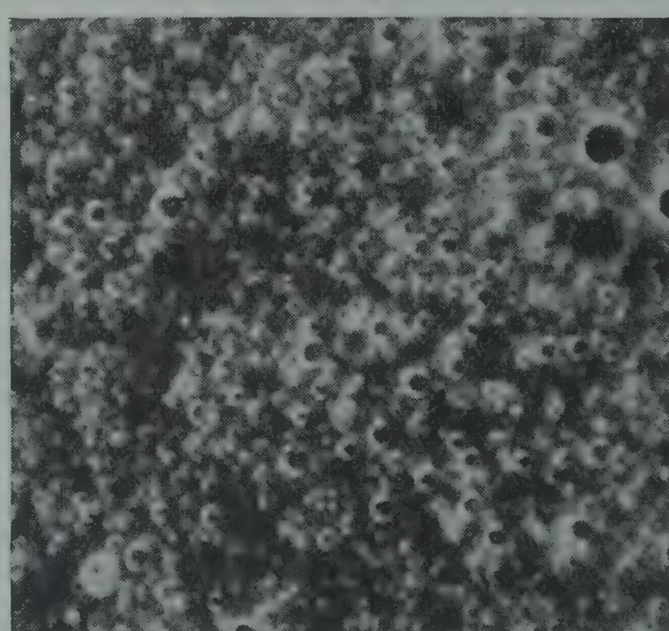


Fig. 86. Worked 66 revolutions no mottles

This experiment shows uniformly small size of water droplets and absence of mottles in unsalted butter at all stages of working process.

Size and Number of Water Droplets in Salted Butter During Working Process Magnified X 740

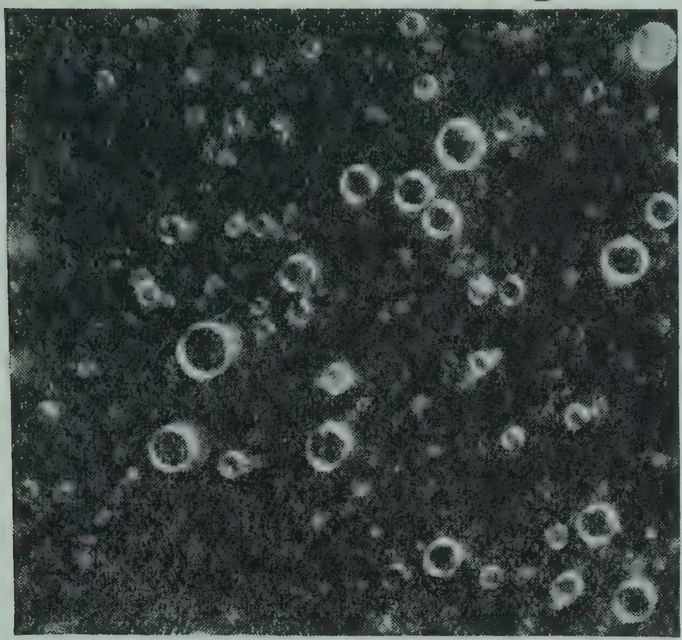


Fig. 87. Worked six revolutions mottled

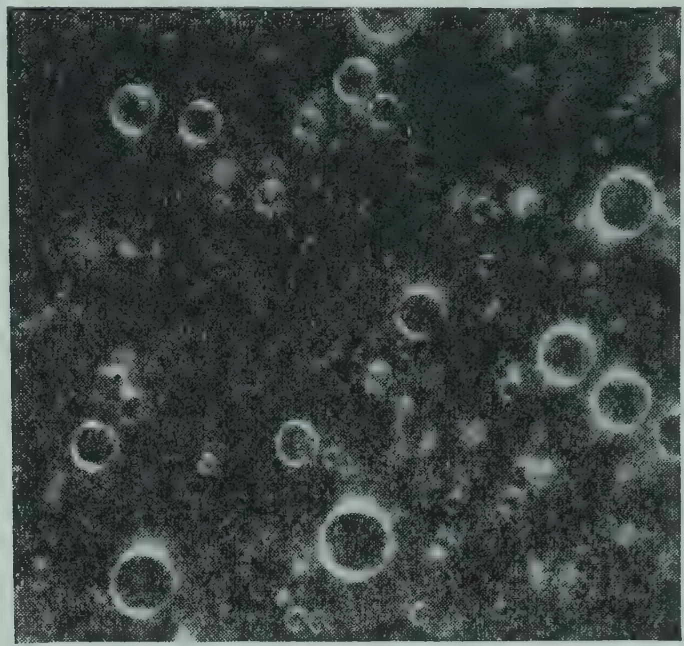


Fig. 88. Worked 12 revolutions mottled

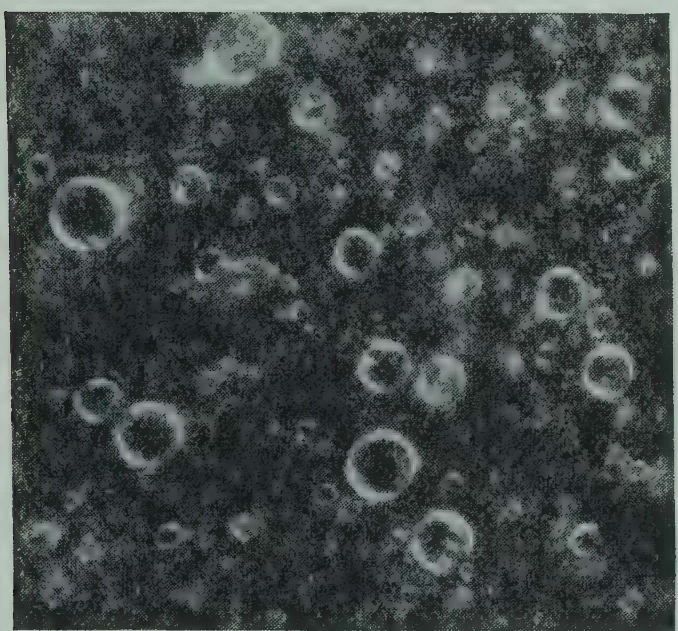


Fig. 89. Worked 18 revolutions mottled

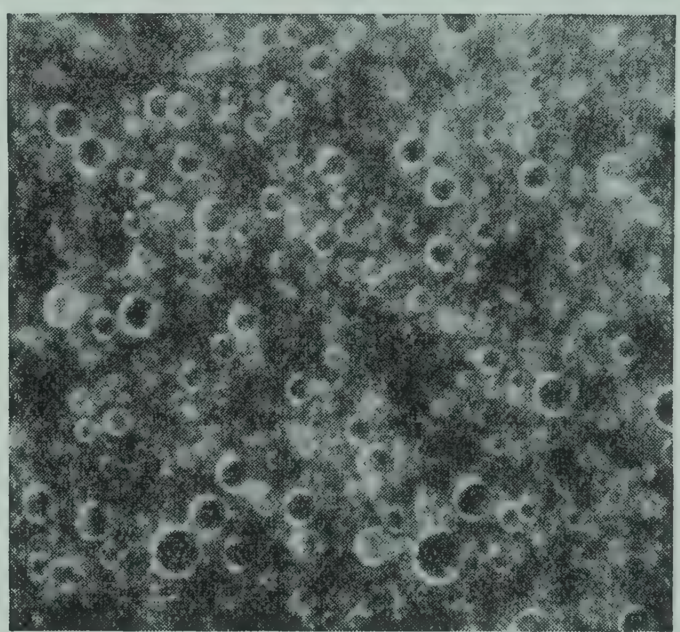


Fig. 90. Worked 26 revolutions slightly mottled

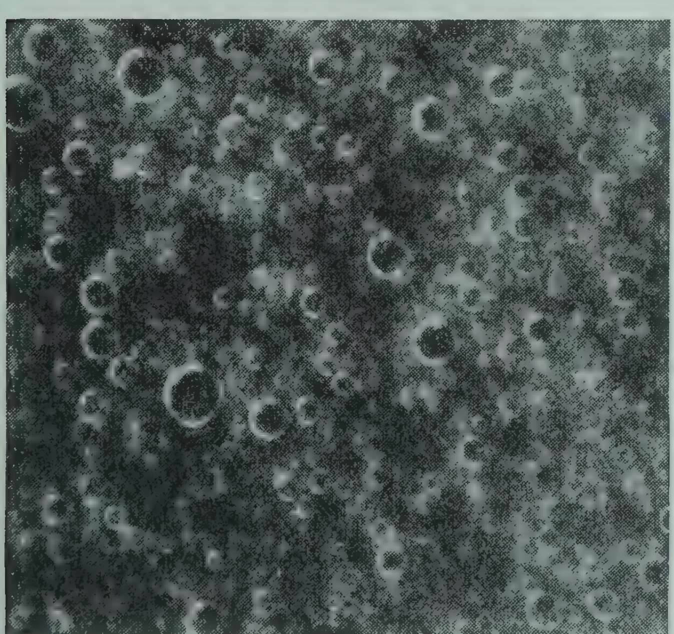


Fig. 91. Worked 34 revolutions no mottles

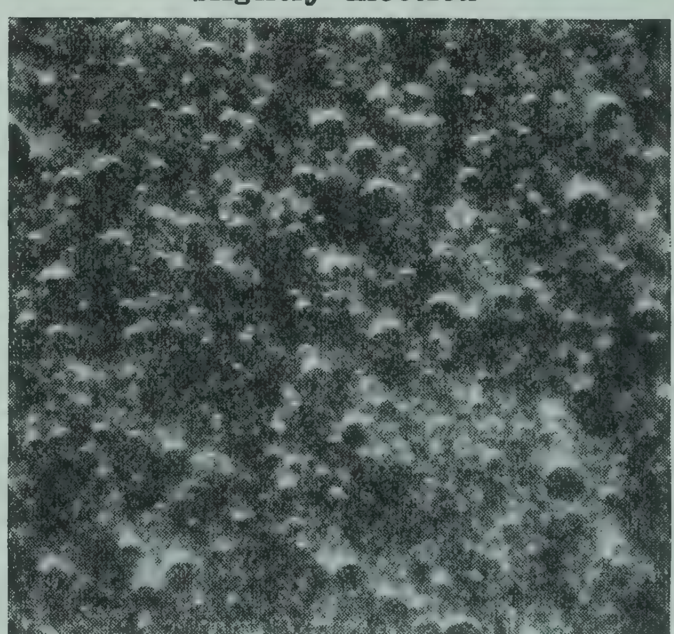


Fig. 92. Worked 66 revolutions no mottles

This experiment shows larger water droplets at beginning and decreasing size toward end of working process in salted butter. Butter worked less than 34 revolutions was mottled.

from cream of good quality, moderate working preserves the pronounced, pleasing aroma. Its desirable character is enhanced, while in the same butter, when overworked—this pleasing flavor and aroma are less pronounced. They are less positive and outstanding. In the case of butter made from cream of inferior quality, underworking or even moderate working accentuates the objectional flavors present, while overworking tends to minimize the coarseness, to make the defect less apparent, and to improve the score.

Effect of Working on Keeping Quality of Butter.—Rahn and Boysen[4] showed that a considerable portion of the moisture of cream becomes sterile in churning by being divided into very small droplets. These findings led them to the conclusion that the amount of infected moisture will decrease if the number of droplets is increased or the size of the droplets decreased and that, therefore, bacterial deterioration of butter may be materially retarded, if not entirely prevented, by working the butter as much as possible without damaging its body. They pointed out further that their deductions probably will not hold true for molds which, unlike bacteria, have the ability to force their way from one droplet to another.

The above results and conclusions are supported in general by the work of Knudsen and Jensen[30] who found that bacterial activity decreased as the working was increased; of Collins and Hammer[5] who reported that migration of bacteria through unsalted butter even when held at favorable temperatures was uncommon, and that the tendency of bacteria to migrate was greater with poorly worked butter than with well worked; of Scharp[31] whose work showed that, as the time of working increased, the number of organisms after any holding period decreased; and of Long and Hammer[32] who inoculated pasteurized cream with an organism known to produce conspicuous deterioration of butter and found much earlier appearance of the defect in the case of underworked and moderately worked butter than in thoroughly worked butter.

The above citations leave no doubt that thorough working tends in the direction of improved keeping quality from the standpoint of absence of bacterial deterioration, especially in the case of butter held at temperatures favorable to bacterial activity. On the other hand, practical experience in commercial

butter manufacture, also supported by experimental data, has conclusively demonstrated that overworking is damaging to keeping quality.

Effect of Overworking on Keeping Quality.—As explained earlier in this chapter, working increases the air content of butter and, since it makes for finer division of the air bubbles, it decreases the size and increases the number of air bubbles present. This in turn augments the surface area of the air and increases the exposure of the butter fat to air. In normally worked butter the air content appears to be only slightly greater than that naturally present due to air incorporation during churning. Guthrie[33] found the average increase of air content of butter due to normal working to be 0.72%. In overworked butter the increase of air is proportionately greater and this increase is accompanied by a much finer division of the air bubbles.

To what extent this increased surface area of air in overworked butter may also encourage bacterial activity that would hasten bacterial flavor deterioration, has not been definitely determined. That it may and probably does encourage bacterial deterioration to some extent is probable because of the fact, pointed out by Rahn,[29] that almost without exception, the flavor-damaging microorganisms are obligatory aerobes which cannot multiply without oxygen.

The deciding cause of damaging flavor deterioration due to overworking, however, appears to lie in the fact that the increased surface area of air in such butter accelerates chemical changes damaging to keeping quality. Thus, Gray and McKay[14] showed that butter sealed in full cans kept much better than butter in partially filled cans. Rogers,[25] and Sommer and Smit[34] demonstrated that overworking encourages the development of fishy flavor in butter. Rogers concluded that fishy flavor may be produced with reasonable certainty by overworking butter made from sour cream, and Sommer points out that overworking distributes the brine more thoroughly, as well as the air, thereby bringing about a more thorough mixture of all the factors concerned, viz.: lecithin, acids, salts, oxygen, iron, copper, thus leading to an acceleration in the production of trimethylamine from the lecithin. Excessive exposure of butter to air also involves the possibility of fat oxidation leading to tallowy flavor.

Our present knowledge of the effect of working on keeping quality of butter compels the conclusion that for best results the butter should be thoroughly worked. In such butter the moisture is finely dispersed and well incorporated. Such butter has a dry body that is free from leakiness and mottles. Overworking to the extent of making the butter salvy, greasy or sticky, jeopardizes keeping quality and should be avoided.

Removal of Butter from Churn.—Upon completion of the working process, the butter is transferred to a butter truck that may hold the entire churning, or to cubes, or tubs, or other containers, according to method of future disposition and marketing.

The manner of removing the butter from the churn is as yet exceedingly crude. In the case of the long barrel churn the butter is generally brought up on the shelf at the churn doors, from where it is "pulled" in small portions by hand or with the help of ladles. In the case of the short barrel churn with door in one end, a tray mounted on a carriage is usually pushed through the churn door and the revolving churn (in low gear) drops the rolls of butter into this tray. In some creameries the long barrel churn is unloaded mechanically by wheeling shallow carrier troughs under the churn, removing the churn doors, turning the churn drum into position with the door frames down and allowing the butter to drop into the carrier troughs. The loaded butter troughs are usually moved to the packing room or cooler by attachment to an overhead conveyor.

The "Setting" of Butter After Working.—When butter is left undisturbed after completion of the working process, either while still in the churn or in the package, the butter hardens; it "sets." This hardening progresses most rapidly during the first 30 to 60 minutes. It continues more slowly after the first hour and after 24 hours there is but little further change.

Hunziker, Cordes and Nissen[35] ascertained this phenomenon by a series of penetration tests on samples from numerous churnings. The butter was subjected to the Perkins' penetration test immediately after working and again at intervals of 30 minutes, and of 1, 2, 24 and 72 hours. During the entire period of the experiment the butter was held at a uniform temperature, i.e., the temperature at which it had been worked.

Representative results of these experiments are shown in Table 42.

The cause of this hardening of butter has not yet been conclusively established. Our present knowledge suggests that after the butter has formed into granules the end point of solidification equilibrium of the butter fat has not as yet been reached. Some of the fat may still be present in semi-liquid form, crystallization of fat is still in progress and requires time for completion. While at rest, the physical status of the butter fat continues to change toward solidification equilibrium and, with fat crystallization advancing toward completion, the butter becomes firmer. It was further noted that in the case of cream that was not held after cooling to churning temperature, the penetration test showed the greatest change during the hardening or "setting" period.

Table 42. Hardness of Butter After Working

Butter Churn Lot Numbers	Temperature of Butter ° F.	Perkins Penetration Test of Butter					
		When Fresh mm.	After 30 Min. mm.	After 1 Hour mm.	After 2 Hours mm.	After 24 Hours mm.	After 72 Hours mm.
1	57	48	34	30	26	18	17
2	55	61	48	38	33	17	16
3	57.2	53	....	39	37	20	17
4	56.5	95	....	50	31	18	....
5	56.8	44	....	35	24	18	....
6	56.4	48	....	37	29	19	....
7	55.0	52	....	37	32	17	....
8	57.8	73	....	56	44	24	20
9	56.0	56	....	50	40	22	....
10	55.0	58	....	37	33	18	17
Average		60		41	34	19	17

The above observations are supported by the more recent work of Mohr and Oldenburg[6] who hold that the hardening of butter after working can be controlled by the temperature of the wash water. They found that the use of very cold wash water (40° F. or lower) produces mass crystallization during the washing process, solidifying the liquid fat present and preventing further formation and growth of fat crystals after working. These investigators observed that butter so washed, while firmer at the churn, does not suffer further hardening after manufacture.

Reworking Butter.—The reworking of butter usually decreases the keeping quality of butter and should be avoided as far as possible. It is probable, though not experimentally proven, that reworking so disturbs the structure of the butter, as to bring about closer contact between bacteria and food supply, thereby enhancing bacterial activity that is associated with microbiological flavor deterioration. The quality-damaging effect of reworking is particularly noticeable in the case of unsalted butter.

Other quality-jeopardizing factors that unavoidably enter into the results of reworking are the mixing of the more or less deteriorated surface butter with its higher germ content, with the remainder of the butter, contamination from printing equipment, and the added incorporation and increased dispersion of air.

Reworking of high-moisture butter, for the purpose of expelling the excess water, is an established corrective practice in the creamery. In such butter the moisture dispersion is usually so minute, and moisture incorporation so complete, that continuation of the working process fails to lower the moisture content. In this condition expulsion of moisture appears possible only by chilling the butter in the cooler and reworking the chilled butter. Inferior keeping quality of this type of reworked butter is obviously not caused by the presence of butter that has suffered surface deterioration. Numerous specific instances have been definitely traced, however, to contaminated churns and worker rolls used for reworking.

Continuous butter cutters that require chilling of the butter before cutting, rework the butter in the operation of printing. Cases of spoilage of the resulting print butter have been attributed to the change in structure caused by reworking. There is available considerable experimental evidence suggesting that the reworking of butter, because it is believed to facilitate access of germ life present to the food supply (buttermilk) and moisture contained in butter, is at least a potential contributing cause of flavor deterioration, provided that the causative germs are present. This evidence is supported also by the experimental findings of Long and Hammer.[37]

In view of the above findings and deductions on keeping quality when using these continuous butter cutting machines, the advantage obviously lies with butter cutters that permit of

cutting the fresh butter direct from the churn. In such case the cutting is not a question of reworking, it is merely a continuation of the working process, temporarily interrupted by transfer from churn to butter cutter; this thus avoids any keeping quality-jeopardizing rearrangement of the physical structure of the butter.

There is no longer any doubt that the reworking of butter in continuous butter cutting machines equipped with the Archimedean screw, hastens and intensifies flavor deterioration of butter that is contaminated with flavor-damaging micro-organisms. Not infrequently the insanitary condition of the continuous butter cutter itself has been found to be the primary source of such contamination and flavor deterioration.

There is, however, no evidence that the passing of butter through these machines itself is harmful to the keeping quality of the resulting prints. The author's experience in the printing of millions of pounds of commercial butter annually by means of continuous butter cutters that require chilled butter and, therefore, rework it, has been consistently to the effect that, with the butter cutter in truly sanitary condition, the printing alone did not jeopardize the keeping quality of properly made butter.

REFERENCES

1. HUNZIKER, O. F., Blue Valley Res. Labs. (not publ.), (1918).
2. HITTCHER, K., Landw. Jahrbücher *51,* 489, (1918).
3. BOYSEN, H., Inaug. Diss. Kiel, (1926).
4. RAHN, O., and BOYSEN, H., J. D. Sc. XI, *6,* 446, (1928).
5. COLLINS, M. A., and HAMMER, B. W., Ia. Sta. J. Sci. VII, *4,* 453, (1933).
6. MOHR, W., and OLDENBURG, F., Molk. Ztg. Hildesheim IIL, 23, 378, (1934).
7. COULTER, S. T., and COMBS, W. B., Minn. Agr. Expt. Sta. Tech. Bul. 115, (1936).
8. LARSEN, C., WHITE, WM., and BAILEY, D. E., So. Dak. Agr. Expt. Sta. Bul. 132, (1912).
9. RUBER, E., Estonia Yearbook D. Prod. Exp. Contr. Bul. 39, (1929).
10. KRAMER, R., and DOERING, H., Molk. Ztg. Hildesheim *44,* (1933).
11. VIRTANEN, A. I., KARSTRÖM, H., Valion Lab. Helsinki, Finland *8,* Ref., (1929).
12. U. S. Publ. Health Service, P. H. Rept. *31,* 41, (1916).
13. MACY, H., Addr. Buttermakers S. Course, Univ. Minn., (1926).
14. GRAY, C. E., and MCKAY, G. L., U. S. Dept. Agr. B. A. I. 84, (1906).
15. WASHBURN, R. M., and DAHLBERG, A. C., J. D. Sc. I, *2,* 114, (1917).
16. DYER, D. C., J. Agr. Res. VI, *24,* 927, (1916).
17. CUSICK, J. F., N. Y. (Cornell) Agr. Expt. Sta. Mem. 30, (1920).
18. RAHN, O., BROWN, C. W., and SMITH, L. M., Mich. Agr. Expt. Sta. Tech. Bul. 2, (1909).
19. HUNZIKER, O. F., MILLS, H. C., and SPITZER, GEO., Purdue Agr. Expt. Sta. Bul. 160, (1912).
20. DAHLBERG, A. C., J. D. Sc. V, *5,* 421, (1922).

21. HUNZIKER, O. F., CORDES, W. A., and NISSEN, B. H., J. D. Sc. XI, *5*, 333, (1928).
22. WEIGMANN, H., Milchw. Zentrbl. *43*, 23/24, (1915).
23. HUNZIKER, O. F., BEHLMER, H. E., CORDES, W. A., and HARRIS, R. C., Blue Valley Res. Labs. (not publ.), (1938).
24. OLSON, H. C., B. W. Hammer Panegyric 65, (1937).
25. ROGERS, L. A., U. S. Dept. Agr. B. A. I., Circ. 146, (1909).
26. PICKERELL, H. M., and GUTHRIE, E. S., N. Y. (Cornell) Agr. Expt. Sta. Bul. 355, (1915).
27. RAHN, O., and MOHR, W., Milchw. Forsch. *1*, 213, (1924).
28. HUNZIKER, O. F., Blue Valley Res. Labs. (not publ.), (1935).
29. RAHN, O., Die Butterbereitung, Wien, (1931).
30. KNUDSEN, S., and JENSEN, M., Maelkeritidende *43*, 1016, (1930).
31. SCHARP, L. R., Victoria D. Mgrs. and Secr's. Asso. Rept. 43rd Ann. Conf. Melbourne, *50*, (1936).
32. LONG, H. F., and HAMMER, B. W., Ia. Agr. Expt. Sta. Res. Bul. 246, (1938).
33. GUTHRIE, E. S., J. D. Sc. XIII, *6*, 461, (1930).
34. SOMMER, H. H., and SMIT, B. J., Wis. Agr. Expt. Sta. Res. Bul. 57, (1923).
35. HUNZIKER, O. F., CORDES, W. A., and NISSEN, B. H., Blue Valley Res. Labs. (not publ.), 1925-26).
36. HUNZIKER, O. F., and HOSMAN, D. FAY, J. D. Sc. I, *4*, 320, (1917).
37. LONG, H. F., and HAMMER, B. W., Ia. Agr. Expt. Sta. Bul. 263, (1939).
38. 22nd Report Danish Dairy Expt. Sta. Hillerod, Denmark, (1939).
39. 24th Report Danish Dairy Expt. Sta. Hillerod, Denmark, (1939).
40. GODFREY, J. H., Director Res. and Publ., Creamery Package Mfg. Company, Chicago, (1940).

CHAPTER XVII

PACKING THE BUTTER

Purpose.—The dominant purpose of packing is to offer the butter to the trade and to the consumer in containers and packages of such size, material, form and appearance, as will best meet the requirements and satisfy the preferences of the buyer, and that will protect the butter from agencies of contamination and mutilation, and against avoidable loss in weight, and deterioration of flavor.

The method of packing and the size, form and material of container or wrapper, differ fundamentally between butter packed for the wholesale trade and butter packed in consumer packages.

BUTTER PACKAGE FOR WHOLESALE TRADE

Containers.—The size and type of container into which butter is packed for the wholesale trade varies considerably with country and section of the same country. In the United States the standard package for the eastern and middle western states is the 63 lb. tub, although some of the bulk butter is also put up in 60 lb. cubes. On the Pacific coast the standard package is the 68 lb. cube. The standard bulk butter package for Canada, New Zealand, Australia, the Union of South Africa and the Argentine is the 56 lb. cube, while Denmark, Germany and the majority of the countries of Continental Europe have adopted the 50 kilo firkin (110.23 lbs. net).

Material of Containers.—Originally butter was packed mostly in earthen crocks. Today the wooden container is exclusively used for bulk butter. Different species of wood are used for this purpose. The standard butter tub used in the United States is generally made of white ash or spruce. The Californian and Canadian cubes are predominatingly made of spruce; New Zealand and Australian cubes are constructed principally of New Zealand white pine; for the Danish firkin teakwood and for the German firkin light color red beech are mostly used.

Most species of wood give the butter in contact with the

container a woody flavor upon prolonged exposure. Some species are more damaging in this respect than others. This defect is particularly serious in the case of storage butter, causing the surface layer of butter to show an objectionable combination of woody and oxidized flavor. Davis and Morbeck[1] studied the odor and flavor-imparting tendency of different species of available woods and listed them in the order of freedom from imparting odor and flavor as follows: white ash, white fir, soft maple, hackberry, sycamore, aspen, beech, yellow poplar, elm, black gum, basswood, cottonwood, red gum and magnolia. They further found that the tendency of wood to impart odor and flavor increases with its moisture content and they concluded that species of wood that contain as much as 20% moisture (partially air-dried) cannot be recommended for butter. Turnbow[2] experimented with spruce, white fir and cottonwood for California cubes and concluded that when cubes were efficiently paraffined and parchment lined, properly seasoned white fir and cottonwood can be used in place of spruce for storing butter in cubes.

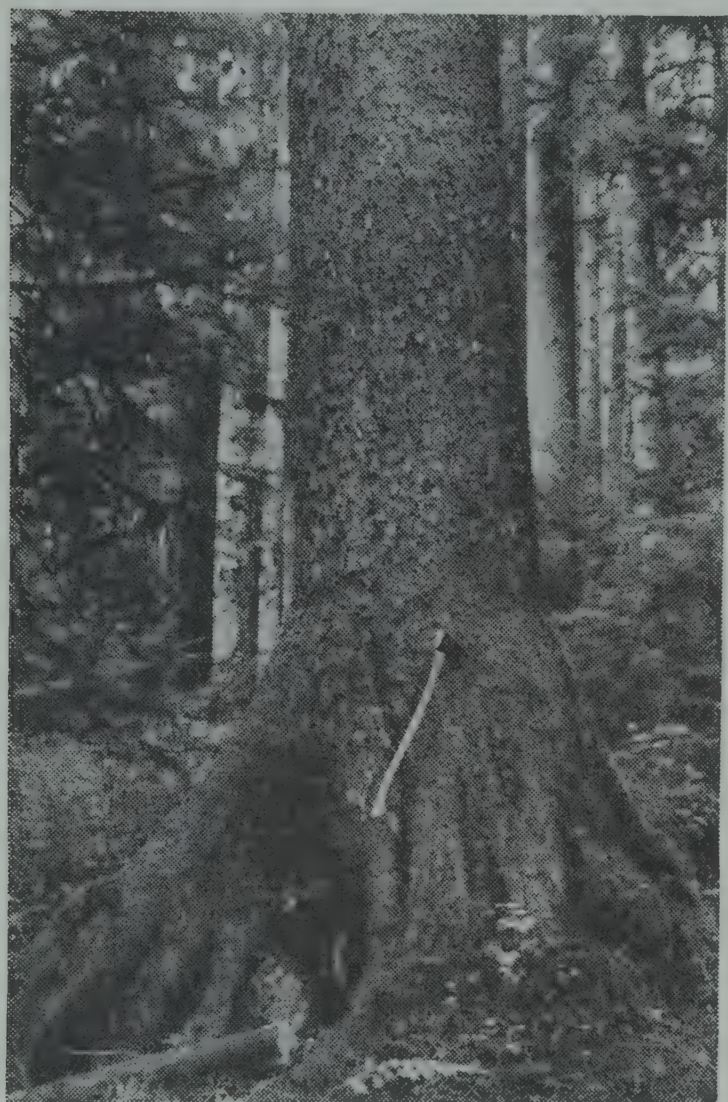


Fig. 93. Sitka Spruce (Picea sitchensis)
Courtesy of School of Forestry, Oregon State College

Treatment of Tubs and Cubes.—In order to minimize the absorption of woody taints, and also discourage contamination of the butter with molds and to prevent excessive loss of weight due to leakage, it has been found helpful to cover the interior of the container with a coating of material that fills the pores of the wood, eliminates direct contact between butter and wood, and makes the wood impervious to water. This has led to the general practice of paraffining the container.

Paraffining Tubs and Cubes.—For best results the container must be dry and preferably hot when the paraffine is applied and the temperature of the paraffine should be well up (260° F. or higher). Paraffine refuses to make a satisfactory bond with a wet surface. It refuses to penetrate and when congealed, will peel off. Heating the dry wood opens its pores, facilitating penetration and the sealing of pores and cracks. With paraffine heated to the proper temperature, efficiently sprayed into the heated container, a smooth coating of uniform thinness is assured. The tub and cube paraffiners available are so arranged as to both steam and paraffine the container. When used with due attention to the proper temperature of the paraffine, they give the container a uniform coating of paraffine that is thin and smooth.

In case of tubs, the staves and bottoms of which have shrunk to the point where a tight tub cannot be secured by adjusting the hoops, soaking in water or brine before paraffining is obviously unavoidable. Likewise, if the tubs show mold spots they should be scrubbed with stiff brush and hot water containing washing powder, then thoroughly rinsed with boiling hot water. Water soaked tubs should be steamed very thoroughly to hasten drying, before they are paraffined.

The tub covers also need proper attention. They often contain cinders, soot or dust gathered in transit to the creamery, or in the creamery stockroom. When the cover is fastened to the tub these impurities drop onto the top circle. It is important, therefore, that the tub covers be thoroughly cleaned before use. All that is usually needed is to turn them bottomside up and flush them with the water hose until free from all foreign matter.

While the paraffining has proved effective in minimizing the danger of mold contamination and in decreasing weight losses due to leakage, its protection of the butter against woody taint and surface deterioration has been disappointing. While the paraffining of the container does assist in minimizing the woody taint and surface deterioration to some extent, it does by no means prevent it. Butter packed in paraffined wooden containers invariably develops a very noticeable woody, oxidized flavor on the surface with age. For the prevention of mold in butter boxes, Neill,[3] and Riddet and Neill,[4] have found the treatment of box timber with a solution of the sodium salt of

salicylanilide, sold in New Zealand under the trade name "Shirlan W.S.," highly effective.

Hunziker and Cordes[5] experimented with the storing of butter in 64 lb. fibre tubs and found that after seven months, the butter in the fibre tubs showed only slight stale flavor on the surface and was much freer from surface deterioration than butter stored in paraffined wooden tubs. Likewise, the objectionable woody taint was entirely absent. However, the loss in weight of butter in the fibre tubs was almost prohibitive, it was 2.7 oz. as against 0.15 oz. in the case of paraffined wooden tubs, and the fibre tubs suffered too much damage in shipment to insure full value for resale.

More recently the treatment with paraffine has been materially improved by the Murray system of wax impregnation, invented by H. L. Murray, New Zealand.[21] In this system only Grade "A" paraffine is used and its temperature is raised to 300 to 350° F. It is heated with super-heated steam coils, and the box boards are treated before the boxes are assembled. The box boards are placed in a vertical position, separated one from the other, on a chain conveyor which travels through the hot paraffine bath. The total period of immersion is two minutes. The high temperature treatment impregnates the wood to a depth of about $\frac{1}{16}$ inch, the wax penetrates the ends as well, it dehydrates the wood, drives off volatile odorous principles, sterilizes the boards. Excess paraffine drains off cleanly, leaving a smooth surface, free from subsequent peeling, and that takes rubber stamp impressions satisfactorily.

Casein-Formaldehyde Treatment of Tubs and Cubes.—This treatment was developed by Wiley[6] of Australia. It consists of applying an emulsion of 50 parts of casein, 7.5 parts of borax and 300 parts of water on the interior of the container, then spraying this coating with a solution of formalin, made up by adding 1000 cc. of water to 100 cc. of 40% formaldehyde (CH_2O).

This treatment has been used successfully for a considerable period in Australia and New Zealand. Experiments by Hunziker, Cordes and Ihde,[7] likewise showed the butter stored in tubs that had been given the casein-formaldehyde treatment to have either only very slight woody flavor or none at all, after six months in cold storage, while surface of the butter in the

paraffined tubs had a pronounced woody taint and stale flavor.

This treatment, as used by Hunziker and co-workers, however, was time-consuming. It required two separate applications, and time was required to permit the casein coating to harden after the formalin spray. It was necessary to treat the tubs on the day previous to their use. The casein-formalin treatment was later simplified by Australian and New Zealand users to the point where the combined spray can be applied in one operation, and proprietary mixtures became available to the industry in those countries.

Wiley experimented with cubes made from such native species of Australian timber as Pinus radiata and Australian Hoop pine, which are abundant in Australia, but which had been barred from use for butter boxes because of their pronounced tendency to taint butter. Wiley reported highly satisfactory results with Pinus radiata when the boxes were given the casein-formalin treatment and were lined with two or three parchments. None of the butter stored for three months in these boxes was tainted sufficiently to suffer degrading. In the case of hoop pine boxes the results varied considerably with the quality of the wood, suggesting that this treatment is not as impermeable to the tainting vapors of hoop pine as it is to those of Pinus radiata.

The Wiley treatment of butter boxes was extensively tested in New Zealand with native species of woods of that country, such as New Zealand Pinus radiata, Tawa (Beilschmiedia Tawa), and Rimu or Imon-pine (Darerydium cupressinum), as reported by Riddet, Valentine and McDowall,[8] and by McDowall and Smith.[9] These investigators concluded that this treatment proved satisfactory for Rimu boxes, but did not protect the butter packed in Pinus radiata, nor in Tawa boxes, sufficiently to prevent objectionable wood taint.

Liners for Tubs and Cubes.—The standard liner for tubs used in the United States is 30 lb. genuine parchment paper, and circles of the same material for top and bottom. The liner is of sufficient width to lap over approximately one inch at top and bottom, and the circles are, or should be, of sufficient size to cover the entire bottom and top of the butter, respectively.

Treatment of Parchment Liners and Circles.—The parchment liners and circles should be thoroughly soaked in hot

saturated brine before use, for added protection against mold development. They should be left in the hot brine for at least 30 minutes. This treatment accomplishes a three-fold purpose. The time-temperature exposure destroys mold spores that may adhere to the parchment. The soaking in the brine frees the parchment from fillers such as glucose, dextrine or glycerine which it may contain for the purpose of making it pliant. These fillers are ideal food for microorganisms. The brine adhering to the parchment helps to inhibit the growth of molds that may be in or on the butter.

The lining of tubs and cubes should be done with care making sure that the ends of the liners in the tubs overlap and that they overlap slightly at the bottom, leaving about one inch projection at the top, to be neatly folded over toward the center after filling the tub.

Aluminum Foil Liner.—Experience in the commercial storage of butter has amply demonstrated that even the combination of paraffined container and parchment liner is incapable of satisfactorily protecting the surface of stored butter against wood taint and oxidized stale flavor. The insufficiency of this protection has stimulated a diligent search for wrapping material more highly impermeable to water, water vapor, light and taints, that is sufficiently pliable to make an intimate bond with the surface of the butter, that has sufficient strength to avoid rupture or bursting, and that does not encourage mold growth.

The work of Riddet, Valentine and McDowall,[10] showed the marked superiority of metal foils waxed to thin parchment, over parchment alone, in protecting the butter in the cubes from wood taints and also against surface deterioration. Barnicoat[11] later experimented with a vast variety of suggestively suitable wrapping materials, such as transparent cellulose colored and uncolored, metal foils, tin-metallized parchment and cellulose, waxed papers, tinfoils and aluminum foils, respectively. After extensive trials, Barnicoat concluded that metal foils waxed to parchment are the only liners that satisfactorily fulfill the exacting requirements of surface protection of butter stored in wooden cubes.

Barnicoat's findings are supported by the work of Hood and White,[12] who reported, after a most exhaustive study of the merits of different thicknesses of aluminum foil adhered to

different weights of parchment, either on one side or on both sides, that all the experimental aluminum foil liners gave a high degree of protection to the flavor and color of the surface of the butter during storage, and they offered the following specifications for aluminum foil liners for butter boxes:

"The aluminum foil used should be 0.0004 inch in thickness and adhered, on both sides with a tasteless and odorless adhesive, to 27 pound pure vegetable parchment."

The aluminum foil cube liner was introduced in New Zealand in 1936 and, according to Hood and White, upwards of 70% of the butter exports of New Zealand to Great Britain are now (1938) packed in untreated wooden cubes lined with aluminum adhering to parchment on both sides. New Zealand uses this so-called "Parchfoil" liner dry (untreated), while Hood recommends for use in Canadian creameries that it be treated, either chemically or by immersion in boiling water. They, therefore, point out that in order to make possible this added precaution against molds, the adhesive in the liner should be of such nature as to withstand either immersion in a cold chemical solution for at least 10 to 20 minutes, or withstand boiling water and the immersion period during cooling, without separation of the sheets. Hood and White further found that one long liner and two end pieces gave slightly better protection to the butter, especially at the edges, than two long liners, but the former were not so easily handled when placing in the box.

Firkins.—The preparation of firkins usually consists of scrubbing the inside thoroughly with brush and hot water containing washing powder, then rinsing with boiling water, followed by cold water. Some factories soak their firkins with brine or sal soda solution for a day prior to final treatment and use. It is customary also to rub salt into the staves on the inside after the last rinse. The firkin is then lined with parchment paper, consisting of three pieces, one each for bottom and top, and one for the side, so cut as to overlap at top and bottom and at the side. Some buttermakers follow the practice of covering the bottom of the firkin with a thin layer of salt and of sprinkling some salt on the top circle.

FILLING AND FINISHING BULK BUTTER

Containers.—The empty containers, properly prepared and lined are now accurately weighed and the tare weight is marked

on their side. If they are weighed without the liners, two ounces should be allowed for the brine-soaked tub liner.

It is advisable to so organize the factory routine as to be ready to pack the butter as soon as the tubs, cubes or firkins are ready. This eliminates the danger of contamination of the empty, treated container from the air. Where this is not practicable, and the containers must be prepared considerably in advance of their use, they should be kept in a clean place protected from dust, soot and flies. Wherever possible, it is advantageous to stack them top against top.

The butter is usually transferred from churn or from the butter truck to the container by hand. For sanitary reasons the use of ladles or scoops would be preferable, but the use of these tools is mechanically impracticable. In some plants the operator wears cotton gloves or rubber gloves for handling the butter. This improves materially the sanitary and ethical tone of operations, and if the gloves are kept scrupulously clean and sterile, it is in fact a very desirable precaution. However, the danger of the gloves becoming a serious source of contamination, and the cost of their care and replacement, have tended to discourage the use of gloves. In the great majority of creameries the butter is transferred with the bare hands of the operator. With finger nails in approved manicured condition and with hands and arms thoroughly washed with soap and water before touching the butter, this practice, though lacking in ethical appearance, is above reproach from the sanitary standpoint. Ladles, tampers and other butter packing tools should be thoroughly washed and scalded daily, and soaked in cold water or preferably cold brine before use, to prevent the butter from sticking to them.

When the tubs or cubes are packed at the churn, they are conveniently lined up in front of the churn, either on the floor, or preferably on platform trucks. Butter from all parts of the churn should be distributed in each container, in order to facilitate uniformity of composition between containers. The butter should be tamped into the tub or cube sufficiently to insure compactness and elimination of air pockets. Loosely packed butter does not keep well. In addition, the presence of air pockets encourages the collection of brine, leakiness, excessive weight losses and unevenness of composition and color. Sufficient care should be exercised while packing to avoid daubing

the outside of the container with butter. The container, completely filled and neatly finished at the top is now placed on scales and the gross and net weights are marked on the package. All containers should be packed to a uniform standard net weight, plus necessary allowance for shrinkage.

The container is now ready to be sealed. The surface is evened off and smoothed over. The top flaps of the liner are neatly folded over and the top of the butter is covered with the properly treated parchment. In the case of tubs the cover is securely fastened down with four suitable four-nail tub fasteners. In the case of cubes the top is nailed down, preferably with five-penny cement-coated wire nails, care being taken that the nails are driven in straight and do not protrude into the butter, or on the outside of the cube. The sealed containers are then plainly stamped on the side and top with the churn

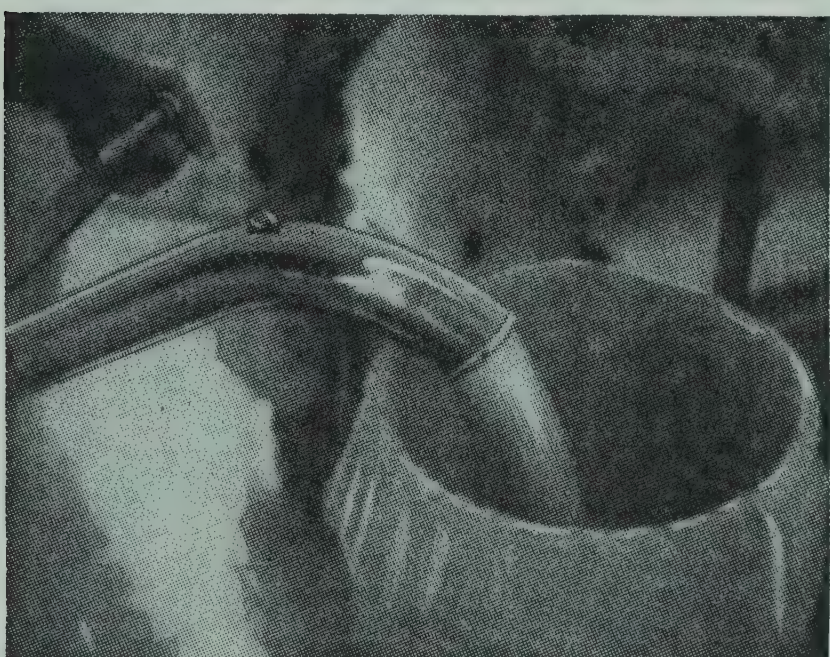


Fig. 94. Packing the Danish firkin by means of compressed air in churn

lot number, and brand, if any, and placed in the factory cooler until ready for shipment. If intended for cold storage, the shorter the time between packing and arrival in cold storage, the better. Prolonged holding at factory cooler temperature (usually about 40° F.) tends to encourage early flavor deterioration.

In New Zealand the packing of cubes by hand has been superseded by mechanical packing. A machine with Archimedean screw, operating on the principle of the continuous butter printer of the Doering type, is used. The mouthpiece is adjustable and of such dimensions as to deliver a block of butter of a size as will exactly fit into their standard 56 lb. cubes. A

cutting frame with adjustable wires cuts the block of butter to the desired length and moves it to the platform scale, where the box is slipped over the butter, and a final section of runway tips the box over for nailing on the lid. This machine is now used in all except a few small creameries for packing bulk butter into 56 lb. boxes direct from the churn.

Weighing the Butter into the Tub.—Some factories are weighing their butter into the container. In this case the containers are not filled at the churn. The entire churning is unloaded into a butter truck, which is then wheeled to the scales. The correct amount of butter, plus weight allowance, is weighed on the parchment-covered platform of the scales and the weighed butter is packed into the container. This is probably the most accurate way of weighing the butter. It has the further advantages that it expedites the unloading of the churn, making it quickly available for the cream of the next churning, and it eliminates the necessity of weighing the empty container, saving time and avoiding one possible source of error.

Weight Allowance for Shrinkage in Bulk Packages.—On the American wholesale market the buyer pays for whole pounds of butter only. He does not pay for fractions of pounds. If upon arrival a tub marked 63 lbs. net, weighs only 62⅞ lbs. on the "up beam," the buyer pays for 62 lbs. only. This emphasizes the importance of accurate scales and accurate weighing at the factory, and of providing for enough extra weight in each container to make allowance for loss in weight in transit or storage.

In order, therefore, to insure full net weight of the package when it reaches the buyer, the container should contain enough butter in excess of its marked net weight, to allow for the possible shrinkage. For the financial welfare of his creamery the buttermaker should exert his best efforts in the manufacture and handling of the butter, to reduce the necessary shrinkage allowance to the irreducible minimum. Experience has demonstrated that under reasonably efficient factory conditions a weight allowance of 4 ounces of butter for 63 lb. tubs is ample. This applies to factories that weigh the empty tub with the liner. If the empty tub is weighed without the liner, the weight allowance should be increased to 6 ounces, thus compensating for the weight of the brine-soaked liner, which is approximately

2 ounces. See also Chapter XX, under "Weight Losses of Butter in Commercial Cold Storage."

Appearance of Bulk Packages.—The importance of the attractiveness of the package cannot be overemphasized. A standard and approved type of butter container, immaculately clean on the outside, with its markings stamped neatly and legibly in the proper place, with the butter at the top free from specks of foreign matter, leveled off evenly, and the parchment clean, fully covering the surface of the butter, and the projecting flaps evenly and neatly folded over, conveys the inevitable impression of quality. Such a package is pleasing to the critical eye of the prospective buyer and puts him in an optimistic frame of mind relative to the merits of the butter.

A slovenly looking container, showing grease spots, dirty finger marks and rusty hoops, and when stripped revealing large cavities and some of the surface not covered by the parchment, specks of foreign particles imbedded in the butter, and the top poorly finished, condemn the quality before the butter is tasted, and if a sale materializes at all, it is prone to occur at a price below that which the butter should bring on the basis of its actual quality.

The attractiveness of the butter package requires close attention to details. The empty container must be clean when it arrives at the creamery. It is difficult to restore a soiled tub to its original impressive freshness and newness by any method of cleaning. The empty container must be protected in the creamery storage room against defilement from dust, soot and dampness. The paraffining must be done with sufficient care to prevent the paraffine from running over the outside of the tub. The handling in the factory must be done with clean hands to avoid unsightly finger marks. The places where the container is set in the creamery and in the cooler must be clean. Its packing with butter must be done in a manner that precludes spilling butter on the outside. The man doing the packing and finishing must take pride in doing a neat job, the factory cooler must be clean and dry, the tubs must be stacked top to top, the men loading for shipment must have clean hands, the car or truck must be clean, tight and free from objectionable odors, and the loading must be done in a manner that precludes shifting of the cargo and smashing of lids. In warm weather it

must be properly iced and provision made for re-icing enroute, as necessary.

The attractiveness of the package is much enhanced by the neatness of its markings. In the case of tubs, for instance, attention to the following details is important:

Use standard size stamps for lot numbers and weights (figures and letters ⅝-inch high). Use standard quality of stamping ink (usually blue), that does not blur. Make markings plain, and square with top of tub. Do not stamp at any promiscuous angle, or place one mark over another. Stamp lot number about one inch below top hoop and weight about one inch below, centered with lot number.

Butter Packed in Bulk for Interplant Shipment.—Butter intended for interplant shipment for printing, such as is often the case with creamery firms operating numerous plants, may be packed at the churn in containers other than those that are approved by the trade as standard. Such butter usually remains in the original bulk package for a few days only, justifying the use of a cheaper container without serious danger of damage to quality. It is customary in such cases to pack the butter into fibre boxes, properly lined with waxed parchment. These boxes may even serve the purpose for re-use. Some creameries use moisture proofed parchment lined paper sacks for interplant shipments of butter.

PACKING BUTTER IN THE CONSUMER PACKAGE

Containers.—While some of the butter output is retailed in the grocery store from bulk packages, the great bulk of butter reaches the consumer in the consumer package which embraces a great variety of sizes, containers, shapes and wraps. The most popular package in the United States appears to be the butter print. This is put up in the form of bars, rectangular blocks and flats, in sizes of one-quarter, one-half, one and two-pound packages. The majority of the quarter pound prints reach the market in packages of four one-quarter pound bars, each wrapped separately, and the four enclosed in a one pound carton. Some butter is retailed also in small earthen crocks (usually holding from five to ten pounds of butter), and in the form of one-half, one, two and five-pound rolls.

Much of the butter that goes to the wholesale trade in the

bulk package is printed by the wholesale receiver, commission man, jobber, or professional butter cutter, before it reaches the retail store. In most of these cases the wholesale dealer packs the butter under his own brand, for which he establishes his own trade outlets. In other cases the retailer has a private brand for which he furnishes the wrappers or cartons, or both, to the wholesaler or to the creamery. Some wholesalers handle prints put up by the creamery under the creamery's brand. Most of the butter which the creamery sells direct to the retail store is sold in prints bearing the creamery's brand or the private brand of the grocer. During fall and winter, when the butter output is at ebb-tide, many creameries print all of their butter.

Roll butter is usually wrapped in a single parchment, and in exceptional cases in parchment and wax paper. Print butter is wrapped either single (one parchment) or double (parchment and wax), or it is single or double wrapped and placed in a carton.

More recently the hotel patty has become popular in some sections of the country. The butter is printed into patties of a size ready to serve. These patties are packed in layers of strips of patties. One pound of butter yields from 40 to 60 patties. The patties may be monographed or bear diverse designs desired by the hotel or restaurant. Their advantage to the buyer is that they are ready to serve and eliminate the operation of butter cutting by the purchaser.

Chilling the Butter Preparatory to Cutting.—The printing of the butter by the use of individual molds requires no previous chilling. When the printing involves the cutting of the butter with wires or knives, the butter at the churn is usually too soft, it lacks the resistance necessary to withstand the pressure that must be applied to push it through the wires, it refuses to cut clean, tends to tear and to mutilate the shape of the prints. This is readily avoided by holding the freshly churned butter in the creamery cooler for a sufficient length of time to chill it to the proper firmness.

Butter cutters that break down the physical structure of the butter yield prints of a very soft texture and, unless the butter is chilled thoroughly before cutting, the resulting prints are generally too soft to withstand handling in subsequent

wrapping, either by machine or by hand, without suffering mutilation.

Butter Cutters.—The equipment available and methods in use for printing butter range from the simple hand mold to ingenious mechanical cutting machines into which the butter is fed continuously, and which deliver the prints neatly wrapped and ready for the market. The hand mold is still in use in connection with farm butter making and in some of the smaller creameries. The butter in such case is transferred from the churn to a table, on which it is printed while soft, by the use of wooden hand molds, or molds with loose bottom in the table top and operated with a hand lever. The butter cutting machines that yield multiples of prints are principally of two general types; namely, cube butter cutters that cut the prints of the desired size from large cubes of butter packed at the churn, by means of mechanically pushing the entire cube of butter through a frame of properly spaced wires; and continuous butter cutters, in which slabs of the unformed butter are continuously fed into the machine that forces them through a stationary mold of the desired dimensions.

Cube Butter Cutters.—Representatives of this type of butter cutter are the Friday, Miller and Simpson cutters. The cubes

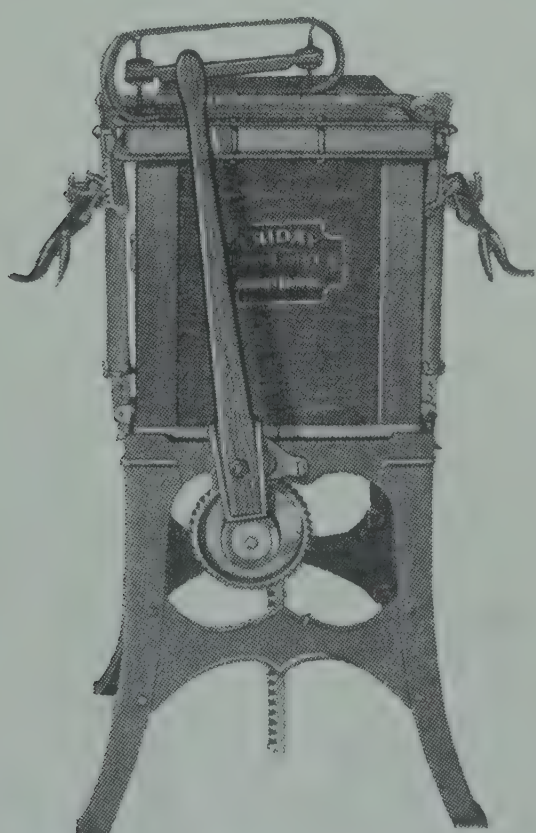


Fig. 95. Friday butter cutter

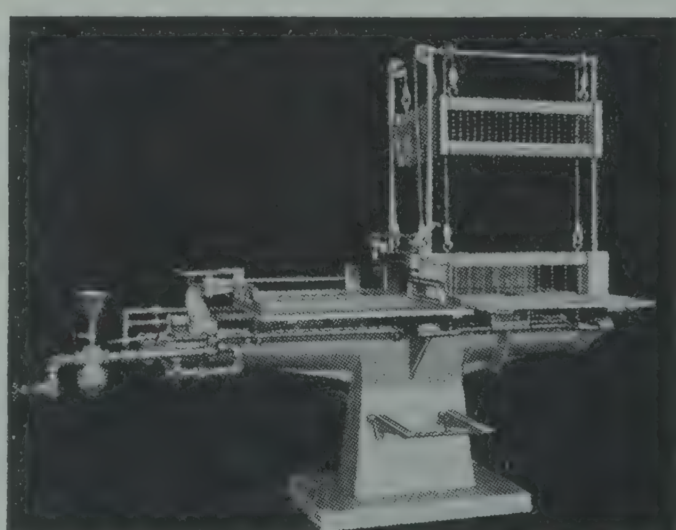


Fig. 96. Miller butter cutter

Courtesy of Cherry-Burrell Corporation

used are of such size and dimensions as to yield a definite number of prints per cube. The boxes are generally of wood, but stainless steel boxes are also used in some of the creameries. They usually are, and always should be, lined with properly treated parchment (preferably soaked in saturated brine). They are packed at the churn and usually require holding in the

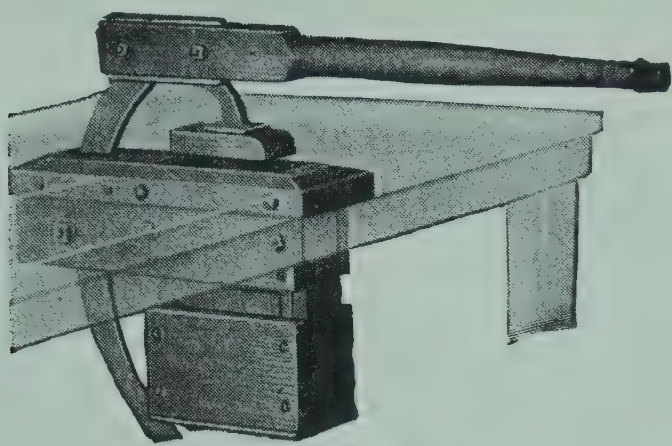


Fig. 97. Hand lever butter printer
Courtesy of Creamery Package Mfg. Company

factory cooler from one to two days for proper chilling. The butter should be chilled to about 45 to 50° F. for satisfactory cutting and neat prints. In cutting these large cubes into prints, the structure of the butter is not disturbed. Their function is confined to the simple principle of slicing by running properly spaced wires through the cube of butter. In order to produce prints that are solid and free from holes, it is indispensable, therefore, that the packing of the cubes at the churn be done with sufficient care to assure compactness and freedom from air pockets in the cubes. This is especially important in the case of butter intended for hotels and restaurants, who cut the prints into small patties. The cube butter printers are of simple construction and their operation requires no mechanical skill. They are used to the best advantage in creameries with moderate output of print butter. Their greatest disadvantage lies in the relatively large amount of scraps they produce.

Continuous Butter Cutters.—To this group belong the Doering, Morpac, and the Benhil butter cutters. In the use of these butter cutters the butter taken from the churn is usually dumped into a butter truck and after thorough chilling, is precut into slabs of a size suitable for easy handling. These slabs are dropped into the hopper of the butter cutting machine, where twin spiral rolls (Archimedean screws) force it through the mold in the header located at the discharge end of the hopper box.

These machines break down the stucture of the butter, they rework it and push it through the header with considerable pressure, thus producing unfailingly compact prints, entirely free from any holes. In destroying the original structure of the butter, however, they change its firmness. The butter is

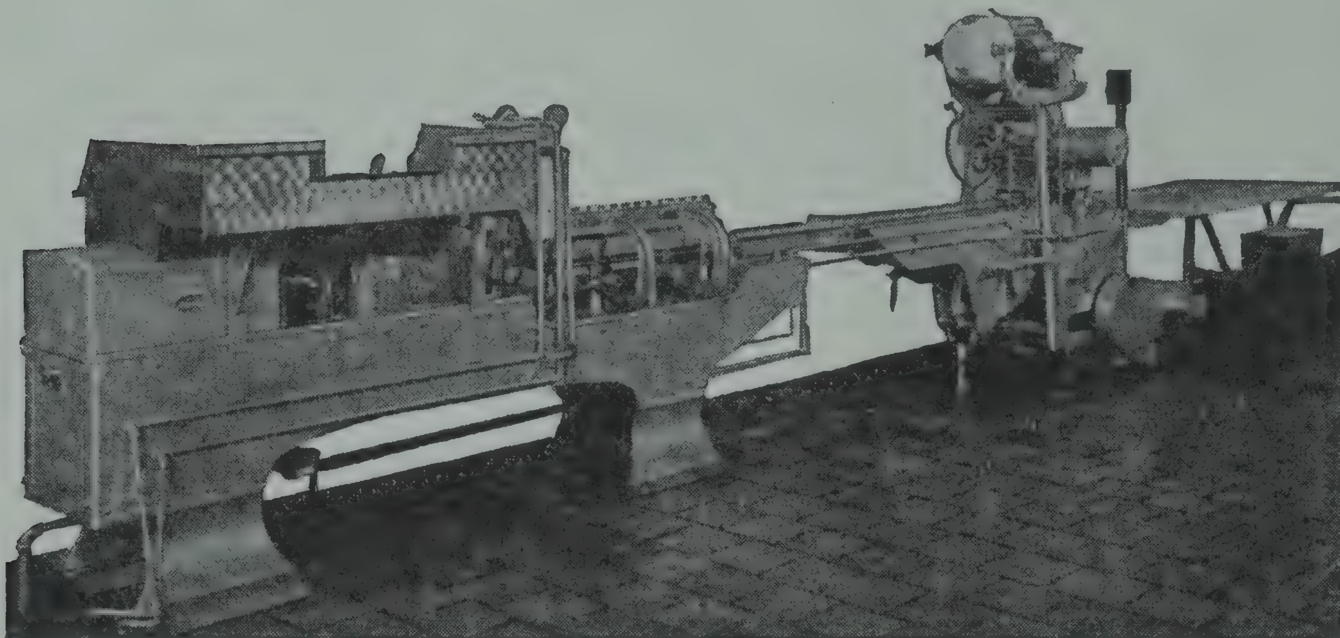


Fig. 98. Doering butter cutter and Automat wrapper
Courtesy of C. Doering & Son

softer and does not entirely regain its original firmness upon subsequent chilling. In order to insure prints of sufficient firmness for satisfactory handling in wrapping, either by hand or by machine, without objectionable mutilation, the butter from the churn requires very thorough chilling. It should be held in the cooler for about 3 to 4 days, chilling it to at least 42° F. preferably lower, before cutting.

In the case of the Doering and the Morpac the header carrying the adjustable mold is jacketed and the twin spiral rolls are of suitable metal and hollow. This permits the circulation of properly tempered water through rolls and jacket, for which pump, motor and connections are furnished. The proper adjustment of the temperature of this circulating water assists in preventing the appearance of mottles on the surface and in the interior of the prints, a defect which may otherwise result from too severe friction on portions of the butter. The tempering effect of the warm water minimizes this friction. The Benhil cutter is equipped with solid wooden rolls and the mold in the header is not jacketed.

Still another type of continuous butter cutter is represented by the Kustner butter cutter and wrapper. This machine com-

bines the continuous principle with the individual mold principle. A hopper receives the pre-cut slabs of butter and an Archimedean screw forces it into multiple individual pockets or molds contained in the periphery of a revolving table. These

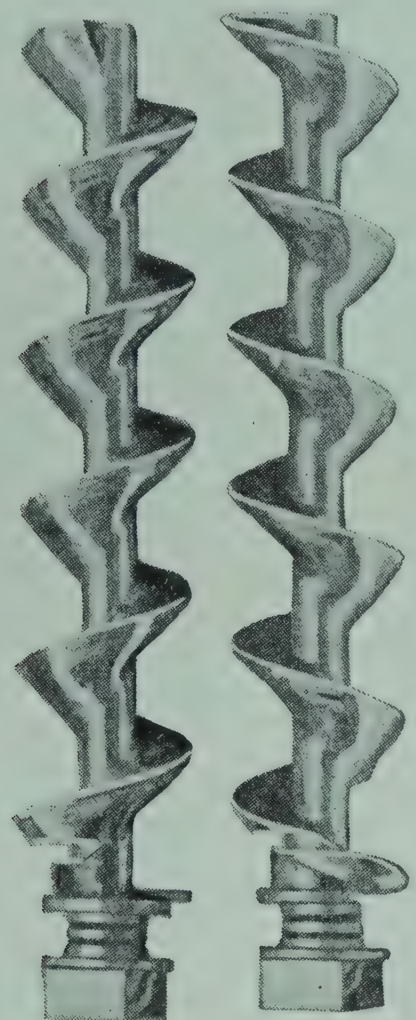


Fig. 98A. Archimedean screw for continuous butter cutter

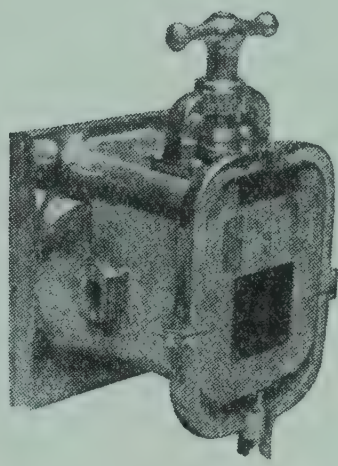


Fig. 98B. Print header

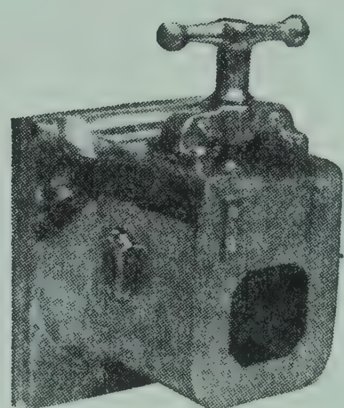


Fig. 98C. Roll header

Courtesy of C. Doering & Son

pockets are automatically packed with the exact weight of butter desired and a plunger from below pushes the prints up and out of the mold. The print then travels to the wrapping attachment. The prints leave this machine neatly wrapped and ready for the market. Because of the ingenious arrangement for mechanical wrapping, these machines are capable of handling unchilled butter direct from the churn without danger of mutilation.

The outstanding advantage of butter cutters of this type is that their operation is mechanical and continuous, which makes for economy of time and labor and uniformity of print weights. These machines are, therefore, especially well adapted for use in creameries with large volumes of print butter. They likewise make possible the printing of butter from any style or size of

bulk package, tub butter as well as cube butter, and they leave no remnants or scraps.

In their operation it is important that the butter entering the machine be all of the same shade of color, otherwise the

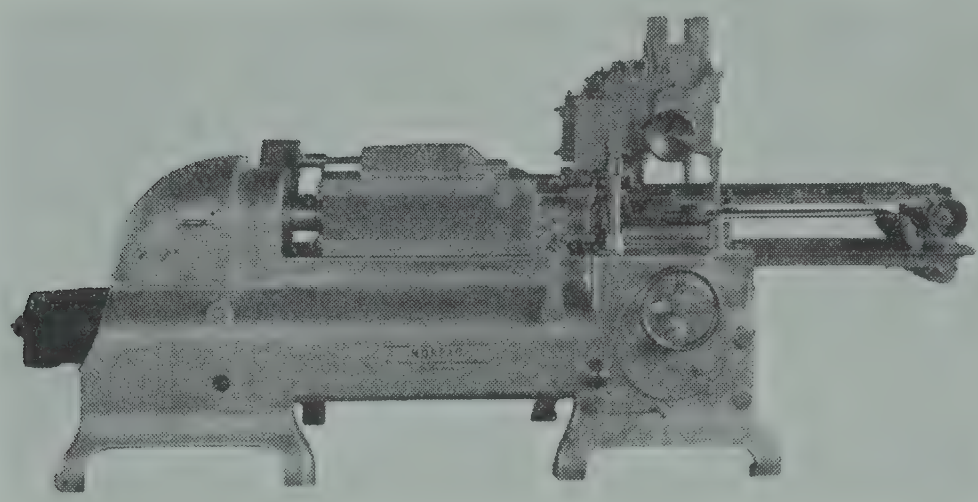


Fig. 99. Morpac molding and wrapping machine
Courtesy of Morris Packaging Equipment Co.

prints will invariably show mottles. The surest means of preventing this lies in examining the butter for color before precutting. If the color is found to vary between different lots of butter, they should be sorted out according to color, so that all butter of one and the same shade can be run through the machine together.

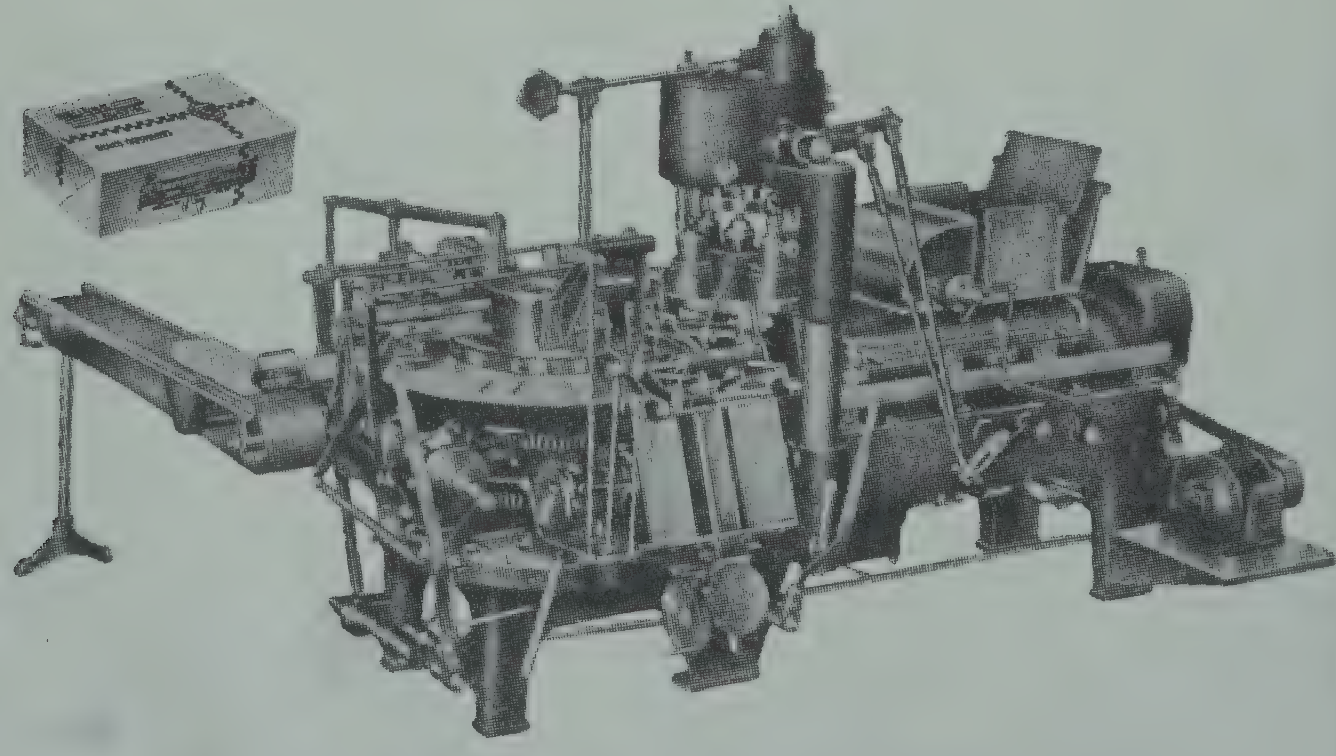


Fig. 100. Kustner butter cutting and wrapping machine
Courtesy of Walker Wallace Co.

Effect of Continuous Butter Cutting Machine on Keeping Quality of Prints.—There appears to exist reasonable uncertainty relative to the effect of the reworking to which the butter is subjected in these continuous butter cutters on the keeping quality of the butter. In Chapter XVI under "Effect of Working on Keeping Quality" it was pointed out that reworking tends to bring the bacteria in butter into more intimate contact with their needed food supply. In addition, the surface butter which may be more or less contaminated, is mixed with the remainder of the package. These conditions suggest increased danger of deterioration, due to bacterial activity. The danger of damage to keeping quality is augmented by the generally insanitary condition of the wooden hopper box that houses the Archimedean screws.

These experiences with the continuous butter cutter with wooden hopper box are common occurrences in the industry. They emphasize the need of most intense treatment to avoid the danger of damaging contamination of print butter. The difficulty experienced in keeping these wooden boxes in satisfactory sanitary condition condemn wooden boxes for the continuous butter cutter and urge their replacement by suitable metal boxes.

Wrapping Prints and Rolls.—The prints are variously wrapped, such as in single wrap with or without carton, or in double wrap with or without carton. The single wrap usually consists of parchment, the double wrap of parchment and wax paper. Similar wraps are used for the rolls, except that rolls are not placed in cartons. Much of the print and roll butter is wrapped in dry wraps, although treatment of the parchment to render it as nearly sterile as possible, is an added protection against mold development on the wrap and on the surface of the butter. In addition, such treatment assists in minimizing weight losses. Parchments for prints and rolls of salted butter are preferably soaked in saturated boiling hot brine, as described under "Treatment of Parchment Liners and Circles," earlier in this chapter. In the case of unsalted butter, brine treatment is objectionable because of the fact that brine-soaked wraps tend to develop mottles on the surface of unsalted butter. See Chapter XXIII on "Mottles." Parchment wraps for unsalted prints are preferably soaked in boiling hot water.

Importance of Efficient Protection of Surface of Print Butter.—The effect of efficient protection of the surface of butter

against agencies that cause surface deterioration, was briefly referred to earlier in this chapter, in connection with bulk packages for the wholesale trade and for storage. In the case of the consumer package, the print and the roll, the importance of surface protection is of even greater magnitude, because of the much larger surface area and because this butter is expected to stand up under a usually much wider range of unfavorable temperature conditions.

Since parchment paper is the conventional material used for butter wraps, it is important that close attention be paid to its quality. It should be of such character as to assist in protecting the butter against molds and against deterioration caused by damaging chemical reactions. In addition it should minimize weight losses due to evaporation and leakage, and it should assist in preventing the darkening of the surface color.

High grade parchment paper is low in water soluble material that provides food for molds. Added protection against this danger lies in the treatment of the parchment in hot brine or hot water. The parchment should be free from visible metallic specks and practically free from soluble metallic salts, such as the salts of copper and of iron, because the presence of these metals and metallic salts hastens damaging chemical reactions by catalizing fat oxidation.

Recent Improvements in Treatment of Parchment Wrappers.—Double wrapping of prints, with parchment and wax paper, affords slightly greater surface protection and slightly less weight loss than the single wrap with parchment. This improvement is slight and no greater than is possible with the single wrap when high grade parchment, waxed on both sides, is used. Heat sealing of the wax wrap, while tending to slightly minimize surface staleness and shrinkage, fails to provide sufficient improvement to justify its adoption for commercial practice. Parchments treated with a harmless antioxidant, such as extract of oat flour (avenized parchment), have been experimentally shown to retard surface oxidation somewhat. Parchments treated with solutions of propionate, such as sodium or calcium propionate, definitely retard mold growth. They do, however, convey to the package a rather pronounced, pungent odor of propionic acid, which may be objected to by the consumer. Parchments so manufactured as to be impervious to the ultra-

violet rays, such as the German products "Ultrament" and "Ultramin," referred to by Riedel,[14] are claimed to have proved far superior to ordinary parchment, relative to surface protection against the influence of light.

Merits of Wrappers Other than Parchment Paper.—Cellulose products, uncolored, such as cellophane, also pliofilm and glassine, in spite of their outstanding transparency, decrease surface deterioration and loss of moisture very materially. This is evidently due to a more air-tight seal. When these transparents are colored dark green or dark red, which colors exclude the ultra-violet light and decrease the transmission of the longer rays, the tendency for surface deterioration is further definitely diminished, as shown experimentally by Stebnitz and Sommer.[15] Cellophane appears more effective in surface protection than Pliofilm or glassine. Aluminum foil and tin foil provide the most complete protection of the surface of the butter. They are impervious to light and make a very snug seal with the butter, as demonstrated by the work of Hunziker and Cordes.[16] While tinfoil is somewhat more effective in providing complete absence of surface defect than aluminum foil, the high cost of tinfoil practically eliminates it from consideration as a wrapper for butter prints. Aluminum foil in direct contact with butter starts early corrosion and pitting due to its corrosiveness in the presence of salt and the acids of butter. The foil also readily tears at the corners of the prints. Simple aluminum foil, therefore, is not suitable for print wraps. However, the "triple foil" called "Parchfoil," consisting of a sheet of aluminum foil between two light sheets of parchment, as developed and in successful use for liners of bulk packages in New Zealand, see "Aluminum Foil Liners" earlier in this chapter, promises distinct advantages as a wrap for print butter that is not intended for quick consumption channels. For prints that reach the consumer within a short time, the double wrap of parchment and wax, or the single wrap of moisture-proof parchment, are preferred because of their lesser cost.

Butter Cartons.—The use of cartons for print butter has become very popular in this country. In America the great bulk of butter in the consumer package is cartoned. The carton adds to the neatness and finish of the package, it protects the shape of the print and assists in keeping the wrap intact and clean,

but contributes considerably to the cost of the package. A good grade of butter carton, printed in two to three colors, costs approximately 0.25 to 0.4 cent. It is customary to use paraffined cartons only. Cold dipped cartons have a heavier and glossier coating of paraffine than hot dipped, making them more nearly impervious to water.

Butter prints are occasionally criticised because of the presence of so-called carton flavor on the surface of the print. Extensive study of this defect has conclusively demonstrated that the usual material used in the manufacture of butter cartons has no effect on surface flavor and that the taint called carton flavor is caused by the ink used on the carton. Inks made up with linseed oil tend to taint the cartoned butter. This danger is greatest in the case of cartons with considerable areas of solid color. The use of odorless carriers, free from linseed oil in the preparation of carton ink, generally eliminates carton flavor. Special attention to the thorough drying of the ink on the carton before the cartons reach the paraffine bath is a further safeguard against the possibility of taint absorption by the butter from the carton.

Hand Wrapping vs. Machine Wrapping.—In plants with a moderate output of print butter, the butter is usually wrapped by hand. An experienced girl is capable of wrapping as high as 4,000 prints per day, without slighting neatness of package. In creameries with large print butter outlets, the use of one or more mechanically satisfactory wrapping machines greatly economizes time and labor and reduces the printing cost, particularly when the operation of the wrapping and cartoning machine is properly synchronized with that of the butter cutting machine, so that cutting and wrapping are reduced to one continuous operation.

Efficient wrapping and cartoning machines are now available, that wrap any size print and seal it in the carton, and that carton multiples of wrapped prints, such as two halves or four quarters in one pound cartons. These machines have a complex mechanism and need the supervision of an experienced mechanic however, otherwise diverse parts may get out of line, causing no end of delays, waste of cartons due to jamming, mashing prints, soiling the machine, and yielding imperfectly wrapped and unsightly packages.

Marking the Wraps.—Similarly as in the case of bulk packages, it is desirable for each print to bear a mark identifying its churn lot number. These markings or lot numbers are the factory's only means for checking back on the manufacture of individual prints. Their value is obvious in times when butter is returned due to quality complaints. They enable the factory to consult the manufacturing record of the defective prints and, by immediate correction of faulty methods, to prevent recurrence of the defect and to guard against costly epidemics of butter spoilage.

The lot numbers or other identifying marks are most conveniently and permanently affixed on the package in the form of perforations in the wrapper. For the perforation of the separate sheets used in hand wrapping there are available hand perforating machines with interchangeable dies for letters or figures. For machine wrapping perforating attachments may be provided, that automatically perforate the wrap for each print, as the wrapping paper reels from the roll.

Packing the Wrapped and Cartoned Butter into Boxes.—The prints and rolls, with or without cartons, are packed in wooden or fibre boxes, usually holding from 10 to 50 pounds of butter, depending on the size of the prints. It is good practice, where the volume justifies the slight extra expense, to have these boxes bear the name and trade mark of the creamery. This adds to the attractiveness of the package and advertises the brand. It is customary and desirable to also stamp the churn lot number on each box.

For cartoned prints, properly chilled, fibre boxes are perfectly suitable and are preferable because of their lower cost, unless the butter is expected to be exposed to summer temperatures in transit to distant destinations. In such case, wooden boxes are preferable. They keep the butter firm longer, and protect the soft butter against jolting which causes objectionable leakage that is destructive to the fibre boxes. In the case of rolls, and prints without cartons, wooden boxes are preferred, as they retain the form of the package better. For uncartoned butter the boxes should be lined with parchment or wax paper, to minimize the danger of wood taint on the surface of the butter and also to guard against mold growth. In the United States, where the bulk of the printed butter is intended for quick

consumption channels, boxes made of spruce, poplar, hemlock or white fir have been found satisfactory to use for uncartoned prints. Turnbow's work[2] shows that cottonwood taints the surface of uncartoned prints. Basswood also is unsuitable, it taints uncartoned prints, as shown by the work of Hunziker and Cordes.[13] The local spruce available in certain sections, that is known by the name Skunk Spruce, is likewise unsuitable for similar reasons.

The flaps of the carton boxes should be securely sealed with an odorless glue and with tape. Sodium silicate glue, three inch tape for 30 lb. boxes and larger, and two inch tape for 10 and 20 lb. boxes, have been found suitable for this purpose. In order to make sure that the flaps are sealed securely, enough glue must be used to cover the entire surface of the flaps. All glue on the tape should be moist so it will adhere to the box. The tape should be put on straight.

The wooden boxes are nailed with four-penny cement-coated wire nails. Care should be taken to avoid splitting of the wood slats, and the nails should be driven straight to guard against protruding inside or outside. The sealed boxes should be transferred to the cooler promptly, as exposure to ordinary temperature hastens deterioration.

The wooden and fibre print boxes should be neatly and legibly marked with churn lot number and size of prints, using standard size stamps (5⁄8 inch) and standard quality stamping ink. On the wooden boxes the lot number is preferably placed at top center on both ends over the hand hold. On the fibre boxes the lot number is conveniently stamped on the tape at both ends of the box. The size of the prints is usually placed at the upper right hand corner of each end of box in the form of such marks as 1⁄4, 1⁄2, or in the case of multiples of quarters or halves in one pound cartons, as 4/4 or 2/2, as the case may be.

Care of Package Supplies at the Creamery.—In order to eliminate the supplies used for packaging butter as a source of damaging contamination, it is of primary importance to provide a suitable place for their storage in the creamery. The place where butter tubs, box shooks, fibre boxes, parchment liners, parchment and wax wrappers and all other packing supplies are stored, should be kept thoroughly clean, dry and free from all accumulations of rubbish.

Supplies that arrive in wrapped or sealed packages, such as folded up fibre boxes, every kind of liner and wrapper, etc., should be left sealed or wrapped in the original package until needed. Supplies left in broken packages should be covered to protect them from air and dust. The storage of these supplies should be sufficiently well organized to provide a suitable and proper place for each type, and the storage room should be efficiently supervised and inspected at regular intervals to make sure that the various supplies are kept in their appointed locations, and to facilitate the permanent maintenance of rigid order and cleanliness.

Weight Allowance for Print Butter.—The Federal and State Laws provide that the consumer package shall be of full net weight at the time it reaches the consumer. A package of butter marked one pound must weigh full 16 ounces net, when delivered to the consumer. While the weight loss of the consumer package, during the usually short interim between printing and receipt by the consumer via grocery store, is or should be very small, some loss, either due to evaporation, or leakage, or both, does occur, even in the case of butter worked to a dry body. In addition, prints not infrequently vary slightly in weight due to unobserved slackening of cutting wires, etc., which may cause some of the prints to be slightly light weight, unless each print is passed over accurate scales, and inaccuracies are adjusted, a practice which is seldom fully carried out.

Because of these discrepancies, avoidable or unavoidable, it is necessary, therefore, to provide for a small weight allowance in excess of the correct net weight. With butter worked to a dry body, with cutting wires tight and wires and header mold accurately adjusted, prints placed on the scales with one wrapper should average at least 16.10 ounces for one pound, 8.07 ounces for one-half pound, and 4.04 ounces for quarter pound prints. Some creameries may need considerably greater allowances in order to provide full net weight by the time the package reaches the consumer. It should be emphasized, however, that even a very small weight allowance affects the returns to the creamery very definitely. Where it is found necessary to materially increase weight allowances, every effort should be made to remove the cause of weight losses that necessitate excessive weight allowances.

Sanitary Care of Butter Packaging Equipment.—The sanitary condition of the equipment used for cutting and wrapping print butter can preserve or break the quality of the butter. A large portion of bacterial butter defects, and epidemics of flavor defects, are traceable to infected equipment in the butter print room.

In order to dependably protect the butter during packaging from avoidable, damaging contamination, there is need of an efficient procedure of washing and sterilizing all tools and equipment with which the butter comes in contact, after each day's work, and this procedure needs to be systematically followed in every detail. Laxness at this point may forfeit the benefit of the painstaking quality-protecting precautions observed in manufacturing operations.

At the conclusion of cutting and wrapping butter, the butter cutting machine should be dissembled to make all parts that come in direct contact with butter fully accessible to cleaning. A thorough cleaning with brush, hot water containing washing powder, followed by a liberal rinse with boiling hot water, will be sufficient for all metal parts, cube printers and butter trucks. In case of a wooden spiral roll box, however, additional treatment is necessary. It has been found helpful to give this box intensive steam treatment. In order to make this as effective as possible, the box is best provided with a tight fitting cover with steam hose connection. A board is clamped over the header opening and live steam is turned into the box through the connection in the cover, for not less than one-half hour.

All conveyor rolls, conveyor belts and the top of the printing and wrapping table need be thoroughly scrubbed with brush and hot alkali water, then well flushed with boiling hot water. After the last rinse the conveyor belt should be treated with chlorine solution of a strength of approximately 100 p.p.m. It may then be raised from the table by putting cleats under the belt to permit circulation of air, and drying out over night, or while not in use. If a wrapping machine is used it, too, needs to be cleansed from all scraps of butter and the parts coming in contact with the butter thoroughly scalded with boiling hot water. The following morning all equipment needs a good rinse with boiling water, followed by a cold water rinse. In addition, it is good practice to rinse the wooden box in which the spiral rolls revolve, with chlorine solution, making sure that the solution splashes over all parts of the interior surface of the box.

Packaging Butter in Tins.—The tin cans used for butter are of a size generally prescribed by the purchaser or exporter. The usual size is that of tins holding 5 pounds net. These tins are completely filled with the butter, thus providing maximum exclusion of air. After packing, the tins are sealed by can sealing machines which crimp the cover on to the can so as to make the seal practically air tight. It is customary for the manufacturer of the tin cans to loan to the creamery one or more sealing machines at a small nominal rental, usually $25.00 per year. The tins when sealed are packed in wooden cases holding sixteen 5 pound tins or twelve 6 pound 6 ounce tins per case. On each tin must be plainly marked the net weight, name of contractor, and date of packing. The interstices between cans must be filled in with paper, sawdust or similar material. The cost of packing in tins, including tins and labor, ranges from about three to three and one-half cents per pound of butter.

The major advantages of canning butter lie in the obvious fact that the hermetically sealed tin can gives complete protection against outside taints, such as woody taints from the cube or tub, and that under temperature conditions that cause temporary melting of the butter, such as in the case of packages exposed to tropical climes, the butter oil stays in the container.

As far as the effect of the sealed tin on the keeping quality of the butter is concerned, the difference between canned butter and butter packed in tubs appears not to be very marked. The early work of Gray and McKay,[17] comparing scores of butter in tubs with scores of butter in tin cans showed no marked differences in either direction, and no material difference was noted between the final averages of all scores for each type of package. Barnicoat[18, 19, 20] comparing butter stored in white pine boxes with butter stored in tins cans, reported that the judges preferred the canned butter when first removed from the package, but that the advantage did not persist for more than one week. In another trial series Barnicoat compared butter in evacuated cans with butter in cans under atmospheric pressure and reported that the packing of butter under reduced pressure appeared to give some slight advantage in the surface quality.

DISPOSITION OF REMNANT BUTTER, SCRAP BUTTER AND RETURNED BUTTER

Churn Room Remnants.—When packing butter to a standard net weight, such as is the case with tub butter and cube

butter, there is usually a remnant of butter left, the last container being only partly filled. If these remnant containers are finished with butter from a succeeding churning, there is danger for the package to show two layers of butter, with different shades of color. The danger of the color of butter to vary between churnings is greatest at the time the cows are changing from winter feed to pasture or from pasture to dry feed. However, slight variations in color between churnings may and do occur at any time of the year. The color of all cans of cream is seldom exactly alike for all churnings, and slight inaccuracies in the amount of color added, if any, together with the fact that no two churnings are worked exactly alike, further affect the color of the butter to some extent.

The trade criticises severely variations in color of the butter contained in one and the same package. In order to avoid such occurrences, the remnant container should not be finished with butter from another churning. The remnant is most satisfactorily disposed of by adding it to the butter of the next churning of the same grade of butter at the beginning of the working process. In the case of the last churning of the day the remnant should be covered with a brine-soaked parchment and placed in the cooler over night. Remnants held in the cooler over night should be tempered the next day, preferably at room temperature, to about the condition of the butter of the fresh churning to which they are added. Creameries having a local outlet for print butter may find it expedient to print their churn room remnants. Such disposition is preferable wherever possible.

Print Room Remnants.—In the case of the cube butter cutter, such as the Friday, remnants from the cubes may be printed with a hand mold. Or, they may be repacked into a cube and rehardened in the cooler for cutting. If the remnants are handled promptly, preventing evaporation of moisture and darkening of color on the surface, the prints from this repacked butter are usually of uniform color. If the remnants cannot be handled without producing irregularity in color, they are best reworked with a fresh churning, as suggested for churn room remnants, or returned to the forewarmer. Similar disposition is recommended for cube remnants which are too small for repacking and that cannot be hand-printed. Remnants of butter taken from

the continuous butter cutter, such as the Doering, at the end of the day, are best placed in the cooler and put back through the machine the following day.

"Scrap" Butter.—During the packing and cutting of butter, scrapings of butter adhering to equipment, wires and cubes, or of butter spilled, accumulate. Scraps that are clean may be placed in a forewarmer containing cream of the same grade. Soiled scraps which cannot be scraped clean, are best melted and the oil strained through a cheese cloth into a forewarmer of undergrade cream. Moldy scraps should be scraped to remove the mold and then handled as soiled scraps.

Returned Butter.—Butter returned to the creamery because of complaints on flavor by store or consumer, should not be allowed to go back to the trade. It should be inspected for flavor, aroma and appearance. If found satisfactory by such inspection, it may then be placed in a forewarmer of No. 1 cream. All other packages of returned butter should be placed in a forewarmer containing undergrade cream. Mold on returned butter should be handled as suggested for moldy scrap butter.

Prompt Disposition of Every Type of Remnant and Scrap Butter.—Remnants from any source do not improve in quality with age. They take up valuable space and may encourage mold development. They should be disposed of daily, thus guarding against growing accumulations of old remnants, scraps and returned butter.

Churnings with Objectionable Extraneous Material.—It occasionally happens that an entire churning requires melting, because it contains objectionable extraneous matter, such as wood particles from accidental splintering of a shelf or roll in the churn, or glass from a broken thermometer or pipette, etc. The importance of precautions that preclude the possibility of such embarrassing occurrences is obvious. When accidents of this nature do happen, the least objectionable means of disposition usually lies in melting the entire churning and straining the oil.

The most practical way of handling the situation appears to be to melt the butter in 10 gallon cans and strain the oil through a cheese cloth into the forewarmer at the rate of one tub (about 60 lbs.) per churning. The addition of oil much in excess of this ratio tends to result in butter with mealy texture.

REFERENCES

1. Davis, E. M., and Morbeck, G. C., U. S. Dept. Agr. Misc. Publ. 250, (1936).
2. Turnbow, G. D., Cal. Agr. Expt. Sta. Bul. 369, (1923).
3. Neill, J. C., N. Z. J. Agr. *51*, 22, 129, (1935).
4. Riddet, W., and Neill, J. C., N. Z. J. Agr. *53*, 3, 129, (1936).
5. Hunziker, O. F., and Cordes, W. A., Blue Valley Res. Labs. (not publ.), (1938).
6. Wiley, W. J., J. Council Sc. and Ind. Res. Melbourne, V, *1*, (1932).
7. Hunziker, O. F., Cordes, W. A., and Ihde, A., Blue Valley Res. Labs. (not publ.), (1933).
8. Riddet, W., Valentine, G. M., and McDowall, F. H., N. Z. Dairy Res. Instit. Publ. 47, (1934).
9. McDowall, F. H., and Smith, J. W., N. Z. Dairy Res. Instit. Publ. 76, (1936).
10. Riddet, W., Valentine, G. M., and McDowall, F. H., N. Z. Dairy Res. Instit. Publ. 48, (1934).
11. Barnicoat, C. R., N. Z. Dairy Res. Instit. Publ. 109, (1938).
12. Hood, E. G., and White, A. H., Can. Dept. Agr., D. D. Res., Ottawa, (1938).
13. Hunziker, O. F., and Cordes, W. A., Blue Valley Res. Labs. (not publ.), (1935-39).
14. Riedel, W., XI. World Dairy Cong. II, 152, (1937).
15. Stebnitz, V. C., and Sommer, H. H., J. D. Sc. XX, 4, 181, (1937).
16. Hunziker, O. F., and Cordes, W. A., Blue Valley Cry. Co. (not publ.), (1935).
17. Gray, C. E., and McKay, G. L., U. S. Dept. Agr. B. A. I. Bul. 84, (1906).
18. Barnicoat, C. R., N. Z. Dairy Res. Instit. Publ. 85, (1938).
19. Barnicoat, C. R., N. Z. Dairy Res. Instit. Publ. 107 (1938).
20. Barnicoat, C. R., N. Z. Dairy Res. Instit. Publ. 108, (1938).
21. Board, F. S., Murray Deodorizers, Ltd., New Zealand, by correspondence, (1939).

CHAPTER XVIII

THE OVERRUN AND UTILIZATION OF BY-PRODUCTS

THE CREAMERY OVERRUN

Definition.—By overrun is understood the difference between the pounds of butter fat churned and the pounds of butter made. The overrun is made possible by the fact that, in addition to butter fat, butter contains non-fatty constituents, such as moisture, salt, curd and small amounts of lactose, acid and ash.

Importance.—The overrun is the financial "vitamin" of the creamery business. Under the present system of creamery operation there is often no margin left between the purchase price of butter fat and the sales price of butter. In fact, in many instances the cost per pound of butter fat is greater than the price received per pound of butter. The creamery must, therefore, largely depend on the overrun to pay for the cost of manufacture and to defray expenses incurred in the purchase of cream and in the marketing of butter.

The Theoretical Overrun.—The theoretical overrun refers to the calculated amount of butter of an assumed fat content, that would theoretically result from a given amount of butter fat. On the basis of an 80% fat standard for butter, for instance, the calculated amount of butter that could be made from 100 lbs. of butter fat would be $\frac{100}{80} \times 100 = 125$ lbs., yielding a theoretical overrun of $125 - 100 = 25\%$. The theoretical overrun ignores all fat losses and discrepancies incurred in practical operation, such as: inaccuracies in weights and tests of milk and cream, fat losses in skim milk and in buttermilk, mechanical fat losses, unavoidable fluctuations in fat content of butter, necessary weight allowances in packing, etc. The theoretical overrun represents, therefore, the maximum overrun that can be produced on the basis of the theoretical relationship of butter fat churned to butter made.

The Actual Overrun.—By the actual overrun is understood the difference between the pounds of butter fat bought and paid

for by the creamery and the pounds of butter actually made and sold. The actual overrun is influenced by such factors as accuracy of weights and tests of milk and cream, fat lost in the skim milk and buttermilk, miscellaneous mechanical losses of milk, cream and butter in handling, composition of butter and weight allowance due to shrinkage. The major items controlling the overrun are tabulated in the "Overrun Chart" as shown below.

Overrun Chart

- The creamery overrun is controlled by
  - Pounds of fat received, paid for and churned. This is influenced by
    - Efficiency of separation of milk.
      - Condition and operation of separator
      - Condition and temperature of milk
    - Accuracy of weights of cream as determined by
      - Accuracy of scales
      - Correct weighing of empty cans
      - Correct weighing of full cans
    - Accuracy of fat test of cream as influenced by
      - Efficiency of stirring
      - Care of sample
      - Accuracy of testing
    - Control of cream losses due to
      - Remnants from cans
      - Samples after test
      - Leaky pipes, joints, valves, pumps, vat gates, churn doors
      - Accidental spilling
      - Foamy cream
  - Pounds of butter made and sold. This is influenced by
    - Exhaustiveness of churning as affected by
      - Temperature of cream
      - Richness of cream
      - Acidity of cream
      - Fullness of churn
      - Size of butter granules
    - Composition of butter as regulated by
      - Moisture control
      - Salt content
      - Accuracy of moisture and salt tests
    - Control of butter losses caused by
      - Remnants in churn, and on packing and printing equipment
      - Soiled butter
      - Weight allowance for shrinkage

Accuracy of Weight and Tests of Milk and Cream—Since the creamery overrun is calculated on the basis of pounds of butter fat received and paid for, it is unavoidably influenced by the relative accuracy of weight and tests of milk and cream. Errors in weights and tests that yield too high results and cause the butter fat paid for to be in excess of the pounds of butter fat actually received, depress the overrun. Short weighing of cream and underreading of tests cause payment for less fat than the pounds of fat actually received and yield a higher overrun than the creamery is legitimately entitled to.

Where the milk or cream is sampled, weighed and tested at the creamery, as is the case with most co-operative creameries and with proprietary creameries operating on the direct shipper system, the door-delivery system or cream route system, this work is generally under the direct control of the creamery operator, and serious inaccuracies can usually be avoided. When the cream is weighed and sampled on the cream route, or when it is weighed, sampled and tested at the cream buying station, or where the creamery accepts the weights and tests of the independent buyer, control is more difficult and inaccuracies are more frequent.

Occasional or accidental minor discrepancies in weights and tests may reasonably be expected. They usually operate in either direction, and over a period of time tend to balance each other. Persistent inaccuracies, all in one direction, however, suggest either gross carelessness and inefficiency, or intentionally and systematically dishonest practices. In either case, a thorough check-up on equipment, operation and individual, followed by whatever action that may appear necessary to eliminate the cause, may be necessary to bring the overrun back to normal.

Persistent discrepancies between cream buying station and creamery weights and tests suggest the need of periodic inspection of the cream station. In such case it is important to make sure that the cream scales are receiving such care that they "break sharply" and weigh accurately; that the cream is sufficiently stirred to yield representative samples; that the cream test balance rests level, swings freely and the weights are correct; that the Babcock centrifuge is run at the proper speed (low speed yields erroneously high tests); that the fat column in the test bottles is clear and not in congealed condition

(especially in winter); and that the tests are read correctly. Such a check-up system, combined with unrelenting insistence on the part of the creamery, of holding the station operator responsible for fat shortages, is an effective means of avoiding low overrun from cream station cream. Purchasing independent buyer cream on the basis of his tests is another prolific cause of low overrun. The creamery cannot afford to buy cream on any basis other than its own weights and tests.

Prolonged holding of the samples before testing is another practice frequently associated with high tests and low overrun, especially in the case of loosely sealed jars, or samples held in a warm room, or both. Wherever possible, prompt testing of the samples is the surest safeguard. See also Chapter IX on "Sampling Cream," and Chapter VII on "Why Cream Tests Vary."

Fat Lost in Skim Milk.—On the basis of 3.8% milk, separated to produce 25% cream, and the skim milk testing 0.057% fat, Mortensen, Breazeale, Meyer and Michaelian[1] calculated that the fat losses in the skim milk reduced the overrun 1.59 per cent. It is obvious, therefore, that whole milk creameries cannot hope to secure as large an overrun as gathered cream creameries. The very marked effect on the overrun, of the small amount of fat lost in the skim milk, emphasizes the importance of securing the greatest possible skimming efficiency in the operation of the factory cream separator, so as to reduce the resulting loss in overrun to the very minimum. For detailed directions on the factors which influence the skimming efficiency of the cream separator see Chapter VII on the "Separation of Milk."

Fat Lost in Buttermilk.—The fat lost in the buttermilk constitutes the largest single factor of fat loss in butter manufacture and it reduces the overrun more than any one of the factors that affect the overrun in normal operation. Mortensen and coworkers[1] showed a decrease in overrun due to the fat lost in the buttermilk of 1.90 per cent, on the basis of cream testing 25% fat, and a buttermilk test of 0.55%.

In commercial butter manufacture the buttermilk test varies within wide limits. It may range from about 0.3 to 1.5%. Under properly controlled conditions and with cream of an average richness of about 30%, it ranges usually about from 0.4 to 0.8%.

For cream of this richness, an average buttermilk test of 0.60% fat may be considered to indicate fairly normal exhaustiveness of churning. Both, the percentage and the pounds of fat lost in the buttermilk are materially influenced by the cream test. As the richness of the cream increases, the buttermilk test also increases, but the actual pounds of fat lost in the buttermilk decreases, as explained in Chapter XV under "Fat Losses in Buttermilk." Because of the dominating influence of the fat lost in the buttermilk on the overrun, daily buttermilk tests and determination of the percentage of the total fat lost in churning are indispensable for maintaining a satisfactory overrun.

Miscellaneous Mechanical Fat Losses.—These losses refer to remnants of milk and cream left in cans, forewarmers, vats, pipes, pumps, fat in foam that is lost, leaks of milk and cream between cream separator and churn, accidental waste by spilling, butter scraps not recovered from churn, etc. These losses vary with the degree of carefulness or carelessness of the factory personnel. While individual items of waste may seem small, in the aggregate they are of sufficient magnitude to play a part in the final overrun. They represent a useless waste and, therefore, should be guarded against as much as possible. Mortensen and co-workers[1] estimated the fat loss from these miscellaneous causes at 0.5% of the total fat received in the whole milk creamery and at 0.2% of the total fat received in the gathered cream creamery, causing a reduction in overrun of 0.62% and 0.25% respectively.

Effect of Composition of Butter on Overrun.—In the United States as well as in most butter producing, exporting and importing countries, butter must contain not less than 80% of milk fat. Theoretically, therefore, the overrun is limited to 25% $(\frac{20}{80} \times 100)$. The higher the fat content above this minimum requirement the lower will be the overrun as shown by the following figures:

Fat in Butter %	Theoretical Overrun %	Fat in Butter %	Theoretical Overrun %
80.0	25.00	82.5	21.21
80.5	24.22	83.0	20.48
81.0	23.45	83.5	19.76
81.5	22.69	84.0	19.04
82.0	21.95	84.5	18.34

The non-fatty constituents of butter, are moisture, salt, and curd. In most of the principal butter producing countries the per cent moisture is legally limited to 16%. The salt content varies largely with market requirements. The great bulk of salted butter made in the United States contains from 2.0 to 2.5% salt. The curd content, including all constituents other than fat, moisture and salt, such as protein, lactose, ash, and acid ranges from approximately 0.4 to 1.0%, averaging about 0.7%. In countries in which the legal requirements of composition are limited to a minimum of fat content, such as 80% fat, as is the case in the United States, the percentage of fat is the sole factor that limits the overrun, and the non-fat constituents are regulated to insure the required percentage of fat. In this case the maximum possible theoretical overrun is 25%. In countries that provide, in addition to a minimum fat limit, a maximum limit of moisture, such as 16% for salted and 18% for unsalted butter, the maximum possible theoretical overrun is less than 25%, unless the limitation of moisture is compensated for by a correspondingly high salt or curd content.

As shown in the preceding table, the composition of the butter has a very marked effect on the overrun. This fact renders efficient control of composition indispensible, if a satisfactory overrun is to be maintained. It should, therefore, be the aim of the buttermaker to so manage his moisture control operations, as to hold the fat content of the finished butter down to as near the legal minimum of 80% as possible.

In order to have the butter of all churnings contain not less than 80% fat, it is obviously not possible to average a fat content of exactly 80%. It is necessary, on account of unavoidable fluctuations in composition, to aim at a fat content slightly higher than 80%. In an efficiently operated creamery an average fat content of 80.5% as the goal may be considered to furnish a reasonable and safe margin. The calculations of overrun offered later in this chapter are, therefore, based on butter containing 80.5% fat, which is equivalent to a maximum theoretical overrun of

$$\left(\frac{100}{80.5} \times 100\right) - 100 = 24.22\%.$$

Weight Allowance for Shrinkage.—The accuracy of the weight of the butter in the finished package has a direct influence on the overrun. Accurate scales and accurate weighing are,

therefore, important. However, in order to compensate for unavoidable shrinkage, it is necessary to provide a reasonable weight allowance. With the butter worked to a dry body and using accurate scales, a weight allowance of four ounces for 63 lb. tubs has been found ample. This overweight causes a reduction in overrun of $\frac{.25 \times 124.22}{63} = 0.49\%$.

CALCULATION OF OVERRUN

The following examples may serve to show the actual overrun that may be expected under average normal conditions of operation in the whole milk creamery and in the creamery receiving gathered cream:

OVERRUN IN WHOLE MILK CREAMERY

Example:

10,000 lbs. of 4% milk are received, 30% cream is separated. skim milk tests 0.05% fat, buttermilk tests 0.60 fat.

Amount of buttermilk calculated on basis of (lbs. cream — 1.2 × fat.)

Miscellaneous fat losses are 0.5% of the total amount fat received in the whole milk.

Butter contains 80.5% fat, weight allowance is 4 oz. per 63 lb. tub.

How much butter is manufactured? How much butter is paid for?

What is the overrun? What is the per cent overrun?

Answer:

Butter fat bought and paid for $\frac{4 \times 10{,}000}{100}$	=	400 lbs.
Skim milk separated $\frac{10{,}000 \times (30-4)}{(30-0.05)}$	=	8681.14 lbs.
Cream separated 10,000 — 8681.41	=	1318.86 lbs.
Butter fat lost in skim milk 8681.14 × 0.0005	=	4.34 lbs.
Butter fat in cream 1318.86 × .30	=	395.66 lbs.
Buttermilk recovered 1318.86 — (395.66 × 1.20)	=	844.07 lbs.
Fat lost in buttermilk 844.07 × 0.006	=	5.06 lbs.
Miscellaneous losses 400 × 0.005	=	2.00 lbs.
Fat in finished butter 395.66 — (5.06 + 2.0)	=	388.60 lbs.

Butter manufactured $388.60 \times \frac{100}{80.5}$ = 482.73 lbs.

Butter sold and paid for $482.73 \times \frac{63}{63.25}$ = 480.82 lbs.

Overrun 480.82 — 400 = 80.82 lbs.

Per cent overrun $\frac{80.82}{400} \times 100$ = 20.205%

OVERRUN IN GATHERED CREAM CREAMERY

Example:

2,000 lbs. of 30% cream received, buttermilk test 0.60%.
Amount of buttermilk calculated on basis of (lbs. cream — 1.2 × lbs. fat).
Miscellaneous fat losses 0.2% of fat received in cream.
Butter contains 80.5% fat, weight allowance is 4 oz. per 63 lb. tub.
How much butter is manufactured? How much butter is paid for? What is the overrun? What is the per cent overrun?

Answer:

Butter fat bought and paid for 2,000 × .30 = 600 lbs.
Buttermilk 2,000 — (600 × 1.20) = 1280 lbs.
Fat lost in buttermilk 1280 × 0.006 = 7.68 lbs.
Miscellaneous losses 600 × 0.002 = 1.20 lbs.
Fat in finished butter 600 — (7.68 + 1.20) = 591.12 lbs.

Butter manufactured $591.12 \times \frac{100}{80.5}$ = 734.31 lbs.

Butter sold and paid for $734.31 \times \frac{63}{63.25}$ = 731.40 lbs.

Overrun 731.40 — 600 = 131.40 lbs.

Per cent overrun $\frac{131.40}{600} \times 100$ = 21.90%

In both of the above examples calculations are based on the churning of cream testing 30% fat. With higher testing cream, the fat losses would be smaller due to the smaller volume of buttermilk, and the overrun would be slightly larger.

The examples further assume that the butter contains 80.5% fat. Some creameries are able to reduce the excess fat in butter to a slightly lower figure and still stay within the minimum fat limit of 80%. Judging from the mass of official butter analyses

available, however, it would appear that much of the butter contains fully 80.5% fat, or slightly more. 80.5% fat as a basis for the above overrun calculations, therefore, appears to be reasonably representative of actual conditions.

The figures for the skim milk and the buttermilk tests, 0.05% and 0.60%, respectively, are quite in line with average performances. To be sure, under highly efficient performance, these tests may be reduced perhaps as much as thirty per cent, which would increase the overrun very materially. For average conditions of actual operation, however, the figures used appear reasonably representative.

Effect of Unavoidable Discrepancies in Weights and Tests on Overrun.—The foregoing examples are based on the assumption that the pounds of fat bought and paid for are determined with mathematical accuracy. They make no allowance for fractions of pounds of cream that fall between the smallest graduations on the beam of the scales; they provide no tolerance for fractions of per cent of fat that fall between the smallest graduations on the neck of the test bottle; and they assume that in the calculations of the returns to the farmer, all fractions of pounds of butter fat are included. In practical operation these discrepancies do exist and their occurrence has a definite effect on the overrun.

Quite frequently either the empty or the full can does not weigh exactly to the whole or half pound. In such case the operator must choose between dropping the undetermined and unrecognized fraction, or calling that fraction one-half or one whole pound. Similar limitations of accuracy occur in the fat test of milk and cream. The smallest graduations on the neck of the standard cream test bottle record one-half per cent and the distance between graduation marks is very small, being limited to approximately one thirty-seventh of one inch. This renders the determination of fractions of less than one-half per cent impracticable, if not impossible. In fact, it is frequently difficult to accurately distinguish the one-half per cent. Here again, the operator must choose between dropping the uncertain and undeterminable fraction, reading to the next lower line, or calling that fraction a whole or a half per cent.

Finally, the pounds of butter fat, as calculated from the pounds of cream and the fat test, often represent an amount with

three to four decimals, rendering the computation of the money due the farmer complicated, time-consuming, uneconomical, and inviting errors in the results. This has led to the practice on the part of the creameries, of dropping some of these fractions, usually including those of the second decimal.

These unreadable and unrecognized fractions in the weights and tests of cream have, in the past, failed to be considered in the treatment of the subject of overrun. They are a fact, however, which the creamery has to deal with. It has no choice in the matter, and collectively they do affect the overrun to a very marked degree in one direction or the other, and to a degree that may not have been fully recognized by the industry in the past.

Since business cannot be conducted successfully by paying for more than is actually received, the creamery cannot pay for butter fat it does not receive and no efficiently operated creamery would tolerate such transactions. Every loyal creamery operator will record only as much weight of cream and as much fat in the test as the cream scales and the Babcock Test actually show. And if the exact weight and the exact test involve fractions which cannot be determined by the standard equipment, and which are not recognized, he ignores these fractions.

A similar practice is in vogue the country over in the purchase of butter and other farm produce. When butter is sold to the produce trade on the open market, the buyer makes remittance for whole pounds only. The butter buyer does not recognize fractions of pounds, nor even half pounds, and he insists on the scale beam touching the top when weighing. If a tub of butter weighs 63 pounds and 15 ounces, the creamery selling this butter would be entitled to and would receive pay for 63 pounds only. This is an established custom, recognized and accepted by the industry.

When the creamery recognizes, records and pays for half pounds of cream and half per cents of the test, and this should be the practice in every creamery, it is paying the farmer more nearly for the exact amount of the product it receives than is the established custom of buying butter and other farm produce. It cannot, as an efficiently conducted business, pay for more than it actually receives, hence it must receive the benefit of the doubt in all cases of unavoidable and unreadable fractions of pounds of cream and of per cent fat in the test.

It may be argued that equity demands the payment for

butter fat on the basis of a "give and take" system as far as these unreadable fractions of weights and tests is concerned, in which case fractions of over one-fourth pound and over three-fourths pound of cream would be recorded as half pounds and whole pounds, respectively, and all fractions of over one-quarter and three-quarters per cent in the test would be recorded as half per cents and as whole per cents, respectively, while all fractions below the quarter and below the three-quarter pounds and per cents would be ignored.

From the standpoint of absolute correctness, this system would be more nearly ideal, but it is impracticable in commercial operation. It is too complicated and confusing to be adaptable to the routine of creamery operation; in fact, it is not done. The unreadable fractions are either not recognized, or they are recorded as half or whole pounds and per cents, respectively. There can be no double method, and since long established custom of the industry accepts, and business competition demands, the ignoring of the unreadable fractions, these fractions are, in fact, ignored.

Other conditions being the same, the increase in the overrun due to the unrecognized fractions varies largely with the amount and richness of each individual shipment of cream; the smaller the amount of fat contained in each individual shipment of cream, the greater must necessarily be the effect of the undeterminable and unrecognized fractions on the overrun. Hence these gains actually amount to more in the case of creameries whose shippers ship largely only in 5-gallon cans than in the case of creameries that receive most of their shipments in 8 and 10-gallon cans.

The following arbitrary example may serve to illustrate the extent to which unreadable fractions of pounds of cream and per cents of fat may influence the overrun, using the same figures as in the example of overrun in the gathered cream creamery previously given. It is assumed that all cream is received in five gallon cans and that all cans, except one remnant can, are full. It is further assumed that each empty can weighs one-quarter pound less than recorded and that each full can weighs one-quarter pound more than recorded; also that the cream test of each can shows one-quarter per cent fat more than is recorded. The 2000 lbs. of cream at a standard weight of 8.3534 lbs. per gallon are equivalent to 239 full gallons, or

$$\frac{239}{5} = 48 \text{ five gal. cans.}$$

OVERRUN IN FARM SEPARATOR CREAM CREAMERY

When Dropping Assumed Fractions in Weights and Tests of Cream.

Fat in cream bought and paid for $2{,}000 \times .30$	=	600	lbs.
Number of 5 gal. cans $\dfrac{2{,}000}{5 \times 8.3534}$	=	48	cans

Gains due to fractions in weight and test of cream.

5-Gal. empty can weighs 12.75 lbs., is recorded 13 lbs.		
Gain per empty can	=	.25 lbs.
5-Gal. full can weighs 54.75 lbs., is recorded 54.50 lbs.		
Gain per full can	=	.25 lbs.
Total gain in weight of cream per can	=	.50 lbs.
Lbs. cream actually churned $2{,}000 + (48 \times 0.5)$	=	2024.00 lbs.
Fat test of cream 30.25%, is recorded 30%		
Gain in test of all cream	=	.25%

Pounds fat actually churned 2024×30.25	=	612.26 lbs.
Amount of buttermilk $2{,}024 - (612.26 \times 1.20)$	=	1289.29 lbs.
Fat lost in buttermilk 1289.29×0.006	=	7.73 lbs.
Miscellaneous losses $612.26 \times .002$	=	1.22 lbs.
Fat in finished butter $612.26 - (7.73 + 1.22)$	=	603.31 lbs.
Butter manufactured $603.31 \times \dfrac{100}{80.5}$	=	749.45 lbs.
Butter sold and paid for $749.45 \times \dfrac{63}{63.25}$	=	746.48 lbs.
Overrun $746.48 - 600$	=	146.48 lbs.
Per cent overrun $\dfrac{146.48}{600} \times 100$	=	24.41%

The above example of overrun calculations is suggestive of the possibilities and limitations of the actual overrun. Its purpose is not to specify what the overrun should be, but to emphasize the importance of consideration of every angle that influences the overrun. It appears consistent that, when calculations make allowance for factors that depress the overrun, such as the fat present in the butter in excess of the legally required minimum of 80%, and for overweight of butter that is

not paid for by the buyer, they should likewise recognize factors that tend to increase the overrun, such as unavoidable and unrecognized fractions in weights and tests that cause some fat to be churned in excess of that for which the creamery pays.

The multitude of operations that influence the creamery overrun and on the sum total of which the actual overrun depends, compels its consideration in terms of operating efficiency. Satisfactory regulation of the overrun demands maximum efficiency in the performance of the numerous details that vitally affect it; efficiency that makes for maximum exhaustiveness of separation and of churning and minimum mechanical losses of milk, cream and butter on the one hand, and correct weighing and testing of milk, cream and butter and efficient control of the composition of butter on the other. It means efficiency also that insures the recording of every fraction of a pound of milk and cream and every fraction of a per cent of fat in the test, that the standard and approved equipment for weighing and testing enables the operator to determine.

UTILIZATION OF CREAMERY BY-PRODUCTS

In addition to efficiency in operation that insures the maximum legitimate overrun at minimum operating cost, and the best quality of butter that can be made from the character of raw material received, there is need of attention to the profitable utilization of the creamery by-products and to the possible diversification of manufactured products.

In the exclusively gathered cream creamery, buttermilk is the only by-product available and diversification that means the manufacture of marketable milk products other than butter is obviously limited. In the whole milk creamery, the chief by-products are skim milk and buttermilk. In addition, its profitable operation is enhanced, and generally makes necessary diversification of manufactured products, including, aside from butter, the manufacture of any one or more of such products as cottage cheese, cheese, ice cream mix, ice cream, fermented milk and other milk drinks, market milk, market cream, whipped cream, butter oil, condensed milk, dried milk, casein and possibly condensed whey products and milk sugar.

Diversification of Manufactured Products.—The soundness of the principle of diversification and its economic advantages

are obvious. Its judicious application provides added potential channels of increased revenues. It makes possible the conversion of every solid ingredient contained in milk into some form of marketable product, and it gives the creamery opportunity to switch its manufacture with the changing demand, supply and market price, to those products that promise the most profitable returns. The advisability of diversification, therefore, merits serious consideration on the part of the progressive creamery operator. Such consideration must necessarily also contemplate the fact that the manufacture of many of the milk products other than butter involves the installation of added equipment that may lie idle and unproductive during at least part of the year, and it may require added technical talent to insure quality products and to avoid losses due to costly defects. In general, therefore, extensive diversification calls for considerable volume of milk supply in order to justify the added investment and operating expense.

Creamery By-Products.—Many creameries are able to return all or part of their skim milk and buttermilk to the farm for feeding purposes at a reasonable return, averaging from one to three cents per gallon. Some creameries have opportunity to manufacture the major portion of their skim milk into quick-consumption products for their local trade, such as cottage cheese, milk drinks, etc. In the case of buttermilk from cream received sweet, a considerable market for fresh buttermilk for human consumption may also be developed.

There is a large annual surplus in the United States, however, of both skim milk and buttermilk, for which other disposition must be provided, in order to avoid total loss. In general, their conversion into standard commodities of the general market, a market that will absorb these products in any volume and at any time, usually promises the most dependable outlet.

Skim Milk.—Creameries with surplus skim milk for which there is no local market, may find it advantageous to manufacture it into skim condensed or skim milk powder, provided that the anticipated volume is sufficient to justify installation of the necessary added equipment. Condensed skim milk in the form of plain or superheated condensed for the ice cream trade and for bakeries, generally promises somewhat higher net returns than sweetened condensed skim milk for bakeries and

confectioners. At times a market is available also for concentrated sour skim milk for animal feeding. Skim milk powder of a quality suitable for human food or food products is a further profitable form of disposition under normal market conditions of supply and demand. Some of the skim milk powder is also sold as animal feed. For average creamery conditions, drum drying is preferable to spray drying, chiefly because of the much lower cost of initial investment required for the necessary equipment. The approximate cost of condensing and drying skim milk is given below.

Manufacturing Cost of Condensed Skim Milk

Items	Cost Per 100 Lbs. Fluid Skim Milk Cents	Cost Per Lb. Condensed Milk Cents	Cost Per Gal. Condensed Milk Cents
Receiving and Separating	3.38	0.101	0.909
Labor	6.50	0.188	1.692
Power, Steam, Water, Refrigeration	14.30	0.428	3.852
Package:			
Bbls. for Sweetened Cond.	....	0.500	....
10-Gal. Cans for Plain Cond.	....	....	0.500
	24.2	1.217	6.953

Sugar 45% @ 5c	2.250
Cost for Sweetened Condensed Milk	3.467 cents per pound
Cost for Plain Condensed Milk	6.953 cents per gallon

The above estimates are based on approximately 33⅓ lbs. of condensed milk per 100 lbs. of fluid skim milk, a package cost of ½ cent per pound for sweetened condensed in barrels, and ½ cent per gallon for plain condensed in 10-gal. cans. The weight per gal. of plain condensed is estimated at 9 lbs. These cost figures do not include any charge for the fluid skim milk, nor charges for overhead, such as administration, maintenance, depreciation and interest on investment. The allocation of overhead per unit of manufactured product necessarily varies with amount of condensing actually done, and must be assessed accordingly.

Manufacturing Cost of Skim Milk Powder.—The cost of drying skim milk is similar to that of drying buttermilk, except

that the steam requirements average slightly lower due to the higher percentage of milk solids in the skim milk. The solids in skim milk average approximately 9% while those in creamery buttermilk seldom exceed 8%, on account of unavoidable dilution of the cream in butter manufacture. The detailed manufacturing cost of buttermilk powder of a creamery with an annual production of 2¼ million pounds of butter and a volume of surplus fluid buttermilk available for drying, that yielded 154,022 lbs. of powder, is given under "Buttermilk" later. The figures show a total cost of approximately 2 cents per pound of finished product, inclusive of package and such overhead items as maintenance, depreciation at 10% and interest at 5% on an investment of $5000.00.

Utilizing Skim Milk for Manufacture of Casein.—Conversion of skim milk into commercial casein has the advantage of relatively small initial outlay for the necessary added equipment and comparative simplicity of manufacture. In general, however, the returns to the creamery from casein are comparatively low.

Casein is utilized either for human food or for industrial purposes. In countries with inadequate supply of high-quality protein for the human diet, conservation and utilization of the milk proteins for purposes of human food is an economic necessity, and the manufacture of food casein is given preference over that of industrial casein. Special methods for this purpose have been developed and are in successful commercial use.

In the United States casein production is predominatingly for industrial purposes. In the average creamery the amount of skim milk available, that is sufficient to justify casein manufacture, is usually limited to a comparatively brief period of the year. It is the common practice of such creameries to manufacture wet curd, selling it to the casein broker who is equipped to do the drying and who pays for the wet curd on the basis of the dry casein it will yield, according to market quotations for dry casein.

The casein broker generally provides the necessary equipment (casein vat) and, in case of reasonable prospects for regular business and short hauls, he furnishes the container consisting of a specially constructed metal receptacle in which he collects the wet curd at reasonable intervals. Otherwise the cream-

ery packs and ships the wet curd to the nearest casein drying plant in its own container (perferably using slack coopered barrels) for which the creamery is credited with a nominal allowance, such as 25c for each container. The casein broker also provides the creamery with such directions for the manufacture of wet curd, as will yield the type of casein best suited for its intended use.

The weight of wet curd produced from 100 lbs. of skim milk ranges from about 7 to 10 pounds, according to moisture content and completeness of casein precipitation. The yield of dried casein averages approximately 35% of the weight of the wet curd. The creamery's returns are calculated on the basis of the yield of dried casein. This varies somewhat with the percentage of solids in the original skim milk. Normally 100 lbs. of skim milk will average a yield of about 2.8 lbs. of dried casein.

For precipitating the casein from the skim milk, either the rennet method or the acid method may be used. For much of the industrial casein the acid method appears to be preferred, chiefly because of the relative freedom of acid casein from ash constituents.

A satisfactory quality of acid casein may be produced by natural souring, or by the addition to the skim milk of hydrochloric acid, or of sulphuric acid. In plants where the resulting whey is to be utilized for recovery of the lactose, the hydrochloric acid method only is suitable. For creameries of limited volume, the sulphuric acid method, using the cooked curd modification, is most commonly employed. With skim milk of good quality and when following a uniform standard of procedure as to amount and manner of acid added, temperature, agitation and thoroughness of washing, accurately following the directions supplied by the casein broker for whom the wet curd is made, the sulphuric acid cooked curd method yields a product of uniformly satisfactory quality. The method is simple, rapid and can be employed with economy.

In the case of creameries intending to manufacture dry casein, the casein broker, likewise, provides the outlet, and he is usually in a position to recommend the type of added equipment needed for pressing, grinding and drying, and to supply directions for the entire process.

The cost of producing wet curd by this method is roughly estimated at from about 2 to 3½ cents per 100 lbs. of skim milk.

On the basis of a 2.8% yield of dried casein, this represents an approximate cost of 0.7 to 1.25 cents per pound in terms of dried casein. The cost of manufacturing dried casein varies much with the volume of production. It is variously given at from 1½ cents to over 5 cents per pound of finished product. For plants of exceptionally large volume the continuous process of casein manufacture offers decided advantages. Such a process has been developed by the Sheffield By-Products Company of New York.

Buttermilk.—The great bulk of semi-solid or condensed buttermilk is utilized for animal feeding purposes, such as for pigs, hogs and chickens. Limited amounts of condensed buttermilk, mostly made by creameries that receive sweet cream, goes into channels of human consumption, being especially preferred for certain culinary uses.

Buttermilk is usually condensed to approximately 30% milk solids. Its cost of condensing is similar to that of plain condensed skim. Its somewhat greater steam requirements due to the lower solids content (approximately 7.5 to 8%) of the fluid creamery buttermilk, may be considered offset by the elimination of refrigeration, the condensed buttermilk being barreled hot direct from the vacuum pan. A further item of increased expense is the barrel, which raises the package cost to about ½ cent per pound, as against ½ cent per gallon for plain condensed skim in ten gallon cans.

Dried buttermilk made from churnings of factory-separated cream or of cream received sweet, is suitable for purposes of human food. That made from churnings of sour, gathered cream is used almost exclusively for animal and chicken feed. Its major outlet is supplied by feed mills which mix it with other feed. The satisfactory drying of buttermilk is somewhat more exacting than the drying of skim milk. Buttermilk powder is more highly hygroscopic than skim milk powder and sour cream buttermilk powder is more so than sweet cream buttermilk powder, and in general has poorer keeping quality. Its pronounced moisture-absorbing properties and its ready tendency to cake, even when held in so-called moisture-proof containers (lined sacks) make prompt disposition after manufacture advisable.

The yield will necessarily vary with the solids content of the fluid buttermilk and the per cent moisture in the finished product. With the moisture content of the dried buttermilk well

under 5%, and an average quality of buttermilk from sour, gathered cream, the yield usually falls within the range of 7 to 8 lbs. of powder per 100 lbs. of fluid buttermilk. The detailed cost of manufacture by the use of a twin-roll drum drier, based on an annual production of approximately 150,000 lbs. of dried buttermilk is given below:

Total Cost of Drying Buttermilk on Basis of 154,022 lbs. of Finished Product

Cost Per 100 Lbs. Buttermilk Powder

Steam 1500 lbs. @ 60c per 1000 lbs. steam	$ .900	
Power 6⅔ K.W. @ 2.7c per K.W.	.180	
Labor ½ hour @ 40c	.200	
Bags and Liners	.200	
Manufacturing Cost =		1.480
Maintenance: $100.00 per year	$100.00	
Depreciation @ 10% on $5000.00	500.00	
Interest @ 6% on $5000.00	300.00	
Fixed overhead on basis of 154,022 lbs. powder, per 100 lbs. powder..........		.584
Total cost of 100 lbs. of dried buttermilk...		$2.064

Costs necessarily vary with diverse local conditions. In assembling the above cost figures on the manufacture of condensed and dry skim milk and buttermilk and of casein, the eventuality of high-price supplies was given due consideration. It should be expected, therefore, that these costs are slightly higher than those that prevail in more favorable locations.

REFERENCE

1. MORTENSEN, M., BREAZEALE, D. F., MEYER, C. H., and MICHAELIAN, M. B., Ia. Agr. Expt. Sta. Bul. 358, (1937).

PART IV

Butter Distribution

CHAPTER XIX

MARKETS AND MARKETING OF BUTTER

The ultimate success of the creamery depends on its ability to dispose of its butter at a profitable price.

Importance of Quality in Successful Marketing.—Quality of product is a fundamental requisite for successful marketing. Butter must be of such quality that there is a demand for it. The consumer is the source of the demand. He is the final judge of quality. The following words of Eschenbrenner[1] of the firm of Gude Brothers, Kieffer Co., New York City, leading Wholesale Distributors of butter, with large retail outlets, may serve to express the practical experience of the butter trade in selling to retail stores, relative to the importance of quality as a sales asset:

"In summing up the whole proposition of marketing butter, it is wholly a matter of quality. When good butter is competing against poorer grades, when high flavored, clean butter is competing against unclean flavors, when solid, waxy-bodied butter is competing against weak-bodied, when desirable color, salt and style is competing against undesirable color, salt and style and general workmanship, on a basis of price and distribution, the better grades get the preference over the poorer grades and the poorer grades are absorbed only after satisfactory concession has been made in price."

Unfortunately the price differential between butter of good quality and undergrades is at times lamentably small, belittling the true importance of quality. In general, these inconsistencies in the price relationship between different grades of butter are usually, though not necessarily always, confined to times of a brisk market (especially in undergrades) and when the demand for these lower grades exceeds the supply. They have to do with the relationship of supply and demand between different grades.

In addition, the tendency in the direction of only a small differential between top grades and ordinary commercial quality scoring 89 to 90 points, is further accentuated by the fact that 89 and 90 point butter is usually centralized creamery butter in car lots, uniform in quality and generally of dependable keeping quality, while much of the top grades, scoring 92 points or better is in small lots, L. C. L., or mixed cars. The different lots making up the mixed car may vary considerably in character, body, color and salt, and while scoring well up when fresh, they are of uncertain keeping quality. The lack of uniformity in character between small lots, either L. C. L. or in mixed cars, necessitates extra handling and assorting for the dealer's trade, and uncertainty as to keeping quality augments the risk of holding and storing.

As a further concrete illustration of preference for large lots with assurance of dependable keeping quality, even if of a somewhat lower score, may be cited the occasional occurrence of cars of Standards of 90 point centralizer butter actually commanding a higher price than 92 point Extras. Such occurrences, while not frequent, are most apt to happen at times during the season when storage stocks are being accumulated. The reason for this apparent inconsistency is probably associated with the fact that "Futures" contracts are made in terms of car lots and they usually refer to 90 point Standards (centralized). This type of butter being most desirable for storage, it can be directly "Hedged." The demand thus created for 90 point butter for storage may, and probably does operate against the demand and the price for lots of smaller size even when of a score higher than 90 points. Again the fundamental cause is that of the relationship of supply and demand.

Nevertheless, under normal conditions and when the supply is equal to or greater than the demand, quality asserts itself and the lower grades are the ones that suffer. Quality, in fact, does control the consumptive demand for butter, making for stability and permanency of the butter market. In addition, quality butter strengthens the industry's ability to successfully meet competition from butter substitutes from within, and from imported butter from without our Country, it is the key to the establishment of satisfactory export markets that will absorb our surplus at home; it decides the creamery's ability to pay the farmer, on whose success the entire dairy industry depends, prices suffi-

ciently attractive to induce him to continue feeding and milking the dairy cow, and to provide him with the indispensable incentive for the production of quality cream.

Influence of Economic Factor on Quality.—The achievement of quality butter is influenced to a large extent by the factor of economic necessity. In the United States, our almost unlimited home markets absorb practically our entire output of butter. This means that we ourselves set the standard of quality for our butter, this standard is not dictated by world competition. But in countries whose returns from their primary products of the farm, exported to and sold on the world market, constitute a dominating part of their national income, quality is indispensable economically for their national welfare. This is particularly true of such leading butter producing countries as Denmark and New Zealand, whose profitable disposition of hundreds of millions of pounds of butter annually depends on the world's market where their butter must compete with that of the leading butter producing countries of the world; where supremacy is synonymous with quality and uniformity of quality; and where quality, therefore, is a compelling necessity.

It is these fundamental differences in economic necessity and in market requirements between these leading butter exporting countries, and the United States with its great home markets, that are responsible, in a large measure, for the general high quality of butter from Denmark and New Zealand, as compared with the relatively large proportion of undergrades that persist in reaching many sections of our home markets annually.

Quality Requirements of Different Markets.—The average consumer wants good butter. Generally speaking, the better the quality furnished, the better he likes it. While butter of the best quality brings the highest price in most markets, there is an appreciable difference in the tolerance toward gradations of quality on the part of the consumer in different markets and in different sections of the same market.

There is a class of consumers that demand extra fine butter and are willing to pay a premium for it. With this class of trade nothing but the best quality will do, and lower grades are rejected. Butter must grade 92, or probably 93 or better, to satisfy this critical trade.

Another class of trade, while insisting on butter with a

clean flavor, firm body, even color and medium salt, is more price-minded, less critical and more quality-tolerant. This group embraces the majority of butter consumers. A good quality of so-called commercial butter, scoring 90 to 91 points, satisfies them.

A still less critical trade accepts without serious complaint butter scoring 89 points, but undergrades of still lower quality, such as butter scoring 88 points or lower, are not wanted for table butter in any appreciable quantity on any market. Such butter must usually be sold at a price so low, that if the farmer were paid on the basis of the quality of the type of cream that produces this low grade butter, he could no longer afford to milk cows.

Grade of Butter Determined by Quality of Cream.—The grade of butter which the creamery has to offer for sale and for which it must find a satisfactory outlet, depends fundamentally on the quality of cream it receives. Whole milk creameries and creameries receiving sweet cream only, are in the best position to manufacture a uniform quality of butter scoring 92 points or better. Such butter, if properly made, is in greatest demand. Its quality facilitates its disposition locally to retail stores, hotels, restaurants, or to food products plants such as ice cream factories, chocolate factories, etc. It likewise is sought by the wholesale produce trade. In the case of creameries receiving sour cream, the usually wide range of cream quality complicates profitable disposition of butter. If the cream is graded for manufacture, a suitable outlet must be found for each grade. Some creameries receiving sour cream do not grade for manufacture, but churn "mine-run" cream. The butter made from such cream is usually of mediocre quality at best. Its profitable disposition will then depend on the ability of the creamery to find a satisfactory outlet for that particular grade of butter. Under certain conditions its disposition in the form of unsalted butter may prove advantageous.

Quality Butter Strengthens Market.—In short, then, the quality requirements of most markets favor the top grades of butter. Such butter definitely stimulates consumption and thereby assists in strengthening the market. Under average normal market conditions its high quality facilitates profitable disposition. The creamery that insists on a good quality of raw

material is in a position not only to simplify its process of manufacture and to hold down operating costs, but its butter, because of its superior quality, is in greater demand and is given preference by the market over the lower grades. On the other hand, the quality tolerances and the price-mindedness of different markets offer a sufficiently wide range of market requirements, to provide outlets for practically every grade of eatable butter. Successful marketing, therefore, requires careful study, on the part of the creamery, of the various market demands, and continuous contact with the channels of trade by which these markets can best be reached. The creamery must find and supply that class of trade which has the greatest demand for the particular grade or grades of butter which it manufactures and for which it must provide the most profitable disposition.

Uniformity of Quality Important.—Having succeeded in finding the most advantageous channels through which to market its butter, the creamery's next problem is to hold these outlets. Success at this point depends to a large extent on its ability to produce and supply the same character and quality of butter uniformly. Uniformity of quality of successive shipments or deliveries of butter is a demand exacted by both the trade and the consumer. It is, in fact, of paramount importance to quality itself. Lack of uniformity is severely criticised by the trade and it tends to cause dissatisfaction and complaints on the part of the consumer.

The difficulty of supplying one and the same market with butter of uniform quality is a problem that confronts every creamery, either because of temporary or seasonal variations in the quality of the raw material, or of irregularities in method of manufacture, or both. In general, this problem is somewhat easier of solution in the creamery with large volume than in the small creamery. With large volume of cream receipts several full size churnings may be made from different portions of the same lot of cream. Furthermore, the grading of the cream for manufacture may provide the grades of butter desired, and in sufficient volume to interest the buyer. The large creamery, likewise, is in position to standardize the various important steps in manufacture. In the small creamery the volume of cream may not be sufficient to make it economical to churn different grades separately. Each churning may represent a differ-

ent lot of cream and there is apt to be a larger proportion of remnant churnings. Some of the smaller creameries may lack adequate equipment for standardization and control of methods of manufacture. The volume of production is often not sufficient to ship in carlots without holding the butter in the creamery cooler so long as to jeopardize quality.

Some of these handicaps of the small creamery have been overcome by mutual co-operation between neighborhood creameries through the formation of county or district associations. Thus, creameries located on the same rail or truck line have organized to jointly ship their butter in carlots and market it through the same distributing agency. In order to improve the uniformity of the butter contained in the car, a competent inspector is employed whose duty it is to standardize their methods of manufacture and to inspect and grade their butter. By means of these or similar co-operative efforts, these creameries are able to produce butter of fairly uniform character and quality, to ship it in carlots, to secure prompt and satisfactory refrigerator service and to make shipments with sufficient frequency to place their butter on the market fresher, in better condition and at less expense.

The standardization of manufacture and of methods of trading and selling has in some instances resulted in the adoption and successful establishment of an association stamp and trade mark. In the State of Iowa these efforts, ably assisted and supported by State officials, have resulted in the establishment of the Iowa State Brand. Butter sold under this brand is enjoying an enviable reputation for high quality and is in demand at a premium in some of the most exacting quality markets in the country. Along similar lines, some of the leading butter exporting countries are marketing their butter on the world market, under well known national brands, such as the Lur Brand of Denmark, the Fernleaf Brand of New Zealand, and the Kangaroo Brand of Australia.

Reputation for Keeping Quality a Factor in Determining Price of Butter.—With the possible exception of butter men of extraordinary knowledge of butter, keeping quality is not determinable by the ordinary method of market inspection for flavor, body and color, or by any other characteristics commonly measured by the usual method of butter scoring. While it may be

determined to some extent by incubation of samples, most dealers must rely on their past experience with individual creameries.

Lack of keeping quality is attributed to, and is in fact largely due to faulty manufacture. Unsatisfactory experience in storing butter from a creamery tends to eliminate the product of that creamery from consideration for storage by that dealer. On the other hand, the product of a creamery with a satisfactory storage record is in demand and may command a premium because of its reputation for keeping quality. Keeping quality, especially in the case of butter intended for storage, thus becomes an important factor in the determination of price. The value of establishing a reputation for keeping quality further emphasizes the importance of legible marks on the package, designating the name or trade mark of the producing creamery.

Nor is the importance of keeping quality limited to butter intended for prolonged cold storage. Even fresh-consumption butter may suffer damaging flavor deterioration by the time it reaches the consumer. The great bulk of fresh butter put up in the retail or consumer's package, or that is retailed from the bulk package in the store, is about three weeks old when it leaves the retail store, and a considerable portion moves still more slowly. Since, in its journey from creamery to wholesaler, to jobber, to retail store, and to consumer, this fresh-consumption butter is exposed to more unfavorable temperature conditions than butter held in cold storage, it is more susceptible to rapid flavor deterioration due to bacterial causes. It is, therefore, of the greatest importance to so handle its manufacture as to guard against definite contamination with species of germ life that are known to cause early spoilage.

DISTRIBUTION

Marketing Dairy Butter.—While the making of butter on the farm has decreased much since the beginning of the present century, Government statistics show that the production of farm butter, or dairy butter, in the United States still amounts to approximately 500,000,000 pounds annually. The major portion of this butter is consumed on the farms where made and on neighborhood farms.

Formerly, when the production of farm butter was twice as large as it is now, much of the surplus over and above that

which was consumed on the farm, was sold to the local country store which generally paid the farmer in trade and not in cash. In the case of the bulk of the farm butter made during the summer months, the supply exceeded the demand, causing accumulations of farm butter at the country stores. Inferior keeping quality of the butter and lack of adequate refrigeration facilities at the stores caused these butter stocks to deteriorate in quality to an extent that rendered the butter unfit for table use. Its only available outlet was the renovated butter factory whose agents purchased it as packing stock at a correspondingly heavy sacrifice in price.

Today, with the decrease in amount of farm butter made, the small volume of butter that is not consumed on the farm is largely sold direct to the consumer, such as to private residences, boarding houses, clubs, restaurants and hotels. The country store may also handle some of it, but its volume is no longer such as to cause annual accumulations at the store. Because of this change the renovated butter factory has practically become extinct.

Selling Creamery Butter.—The producer creamery is selling its butter through one or more of the following principal channels: Local sales for home consumption, direct sales to some retail food chain organization, sales through its own centralized distributing agency with sales branches in the large consuming centers, sales through affiliation with a central selling agency, sales to the operator of a concentration plant, and selling to a receiver of the wholesale produce trade at some central market.

Selling Butter Locally.—In general the best and most profitable markets are those nearest home. Selling butter locally, either over the counter at the creamery, or by going direct to residences, or through local retail stores, or public or municipal markets, or to restaurants, hotels, clubs, or by parcel post, or shipping it direct to similar outlets in neighboring towns and cities, has many advantages. It eliminates the heavy overhead of a large selling organization with sales branches in distant markets, it enables the creamery to reduce the number of middlemen or to do without them entirely, thus netting the creamery a larger portion of the consumer's or retailer's dollar. It saves the cost of transportation to distant points, which may amount to 1 to 2 cents or more. It helps to protect the butter

against conditions in transit unfavorable to its quality. It reduces the interval between manufacture and consumption, thereby enabling the creamery to supply the consumer with a fresher butter which may command a better price. It minimizes the danger of quality complaints, it tends to reduce the volume of returns and loss due to spoilage, and its quicker turnover assists in reducing shrinkage due to weight losses. It gives the creamery the best possible opportunity to sell its butter in the consumer's package, the print, roll or patty and under its own brand, thereby establishing its trade mark and developing a permanent demand for it.

Direct consumer sales may further be developed through what is known as the club buying system. Clubs whose members are consumers, are organized by a local individual in the community. He buys butter regularly and usually in sufficient quantity per shipment to supply all the members of his club. This has proved an effective means of promoting direct consumer sales, and of profitable marketing provided that the club buyer is a responsible individual. The amount of butter which the creamery can dispose of through the club system is usually limited, however.

One of the difficulties encountered by the average small creamery in catering to direct local sales lies in the irregularity of the amount of its butter production throughout the year and the fluctuations in the demand of such local markets. The situation is somewhat similar to that of the retail milk business. Fluctuations in production and in demand for the product seldom synchronize, often causing a succession of feast and famine.

The operation of delivery routes likewise has its problems. Unless the number of stops and the volume per stop are sufficient to insure a fair tonnage for each sales route, the cost of delivery may become excessive. In strongly competitive markets that curtail the volume of butter per stop, diversification of products sold by the creamery may become a compelling necessity for the successful operation of delivery routes.

Selling Butter to the Operator of a Country Concentration Point.—The concentration point has become a considerable factor as a market for the butter output of creameries in sections of the central and north central west. It buys butter from individual creameries, and assembles it for packing and shipping. There

is usually a definite sales agreement as to price, based on some market quotation, generally New York or Chicago; place of delivery, either at the producer creamery or at the buyer's concentration plant; and style of package, whether in bulk or in prints or rolls, etc. Often the buyer furnishes the package material.

Selling Butter to the Wholesale Produce Trade.—Distribution of vast quantities of the butter made, is taken care of by an organization of middlemen intermediary between the shipper and the city retail stores. This organization is known as the wholesale produce trade. It occupies an important position in supplying the shipper with a market for his product and in regulating the quantity and quality of the supply of the retail store. It reduces the cost of transportation by making possible shipments in large units. It maintains the necessary business relations with the retail stores for or in the place of the shipper, and makes possible prompt payments so as to enable the shipper to pay the farmer for his cream without delay. In other words, the wholesale produce trade performs that function which the shipper—the creamery—without branch offices in the distant city markets, is unable to accomplish. It acts as a clearing house for the shipper and retailer alike. Its proximity to distributing channels enables it to feel the pulse of the market in its and other cities and to regulate the influx and movement of the various grades of butter and other commodities on the market.

Wholesale produce trade organizations are established in all cities of appreciable size. According to Weld,[2] "a city is large enough to require a separate wholesale trade organization when it can handle goods in car lots for consumption in the city or for redistribution in nearby towns."

The wholesale dealers may be divided into two classes, to each of which are attributed certain, more or less definitely defined functions. These are, the middlemen who receive goods direct from the shipper, and the middlemen who buy direct from the receivers and sell to the retail stores or other outlets.

To the first class belong the wholesale receiver, the commission man and the broker. The wholesale receiver buys the butter outright and pays the shipper for it upon receipt. He sells the butter to the retail store and also to the jobber. The commission man does not buy the butter, he does not become owner of it, but acts as an agent for the shipper, selling it for

him to retail stores, hotels, restaurants, and other outlets, deducting from the gross receipts a commission for his services, together with freight and cartage charges. The broker operates on a plan similar to that of the commission man, but he usually handles goods in larger quantities and charges a lower rate of commission.

To the second class, the middleman who buys from the wholesale receiver and not direct from the shipper, belongs the jobber. He also sells to the retail trade.

These middlemen have their organization of solicitors who look after the retail trade and other outlets in their own as well as in other cities. Most of the butter shipped to the wholesale trade is desired in bulk packages, usually 60 to 63 pound tubs or 50 pound boxes for Eastern markets and 68 pound cubes for the Pacific coast markets. In exceptional cases the shippers put up their butter in the consumer's package, the print, patty or roll. The receivers sell their butter both in the bulk package and in the consumer's package. For the latter they generally have their own brand or brands, on the trade mark of which they have developed trade outlets.

Methods of Sales.—Butter shipped to the wholesale trade is sold by any one of the following four methods:

1. **Track Sales.**—By track sale is understood F. O. B. (free on board) shipping point. By this method the responsibility of the shipper ceases when the butter is placed in the car, or on ship board, at the shipping point. The buyer pays the freight and cartage, and assumes the risk of transportation, and agrees to pay a definite price, based on quotations of the leading markets, F. O. B. track. The creamery knows exactly what it will receive for its butter at the time it is shipped, and payments are made upon arrival of the goods at the market. From the shipper's or creamery's point of view this is the most advantageous method of selling butter to the wholesale trade. In order to sell butter under this agreement the creamery must previously satisfy the receiver as to uniformity of quality, workmanship, composition and color of butter that the creamery is capable of supplying. This is usually done by trial shipments.

2. **Delivered Sales, or F. O. B. Market.**—By this method of sales the shipper's responsibility ceases when the butter has reached the buyer's market. The shipper pays the freight and

cartage, and assumes the risk of transportation. The price depends on market quotations on the date of arrival. Agreements to buy butter on the above basis are usually likewise made only after previous receipt of trial shipments representative of the quality of the average run of butter manufactured by the contracting creamery. While not as advantageous to the creamery as the first method, because the price is determined at the market end and because the shipper must pay the freight and assume the risk of transportation, this method is usually preferable to commission sales, discussed under method 3.

In both methods 1 and 2, the butter sells at a definite price, based on market quotations. According to these methods of sale the buyer agrees to pay the price stipulated on the basis of market quotations, as long as he is willing to accept the butter. Should the butter of some shipments not measure up to the quality of the trial samples, the buyer will still pay the price agreed upon, but will notify the creamery of the defect, so it may be remedied promptly. In case the quality continues to be inferior to that of the trial shipments, the buyer may ask the creamery to find another outlet for its butter, or else negotiate another agreement satisfactory to both parties.

3. **Commission Sales.**—In contrast to track sales and delivered sales, commission sales are not made on the basis of a prearranged sales price according to market quotations. The commission man, who is the receiver in this case, does not buy the butter. He merely acts as an agent to sell butter for the creamery, for which service he charges the shipper a commission, usually amounting to 5% of the gross receipts. The shipper pays the freight, cartage and assumes the risk of transportation.

The returns are made on the basis of the market score reported by the commission man. Most commission men not only act in the capacity of agents for the shipper, but also buy butter outright. In such case it is obviously to their advantage, on an advancing market, to purchase outright and on a declining market to adhere to the commission basis. It may also happen that the commission man charges the shipper a commission on goods purchased outright, and thus receives a commission on his own purchase.

Commission sales, therefore, place the creamery inevitably at the mercy of the commission man. Unless he sells it under

the "call" of the Mercantile Exchange and attaches the Official Inspection Certificate of the Exchange to the memorandum of sale that accompanies his remittance to the creamery, the creamery has no guarantee that the returns received represent the price at which the butter was actually sold.

4. **Contract Sales.**—In contract sales the shipper enters into a contract with the dealer agreeing to deliver a certain number of pounds of butter per week at a price based on market quotations. The contracts are usually short-term agreements and are largely, though not always, confined to the storage season. Contract sales are usually taken advantage of by large creameries. Small creameries with a limited and often uncertain output are seldom in a position to negotiate such sales and, when consummating them, they are liable to find serious difficulty in fulfilling their agreement.

Methods of Payment.—Creameries shipping to the wholesale produce trade usually draw on the receiver or commission man to the extent of about 80% of the value of the shipment at the time of shipment. This is done by draft attached to the bill of lading. The receiver or commission man pays for the balance of the shipment upon arrival of the goods or upon their sale, respectively.

Trading in "Futures."—Trading in "Futures" is limited to the Chicago market and the transactions are cleared through the books of the Chicago Mercantile Exchange. It is confined principally, though not exclusively, to Standards of 90 point quality. All trading in futures is in carlots.

"Futures" sales are contracts for delivery at some future date. Unlike "spot" sales, which require the transfer of ownership of butter within a few hours, "futures" sales do not require immediate delivery. A "futures" contract may be satisfied and is terminated by either one of the following two methods:

a. By delivery of the butter at the time specified by the contract.

b. By offsetting the **sale** of the "futures" contract by the **purchase** of a similar contract rather than by delivery of the butter. The following example may serve to illustrate the transaction:

A dealer sells a car of butter through the Mercantile Exchange to a broker for delivery in November. The carrying charges for

the six months in storage are 1¼c. The "spot" price quotation on the day of sale is 22½c and November "futures" is quoted at 23¾c. The spread between "spot" and "futures" prices thus covers the carrying charges. The dealer who is the owner can, therefore, hold and store his butter for delivery in November, with little risk. His "futures" contract protects him against loss which might result in case of a declining market. For the purpose of this example let us now assume that a strong market during the summer months causes a considerable rise in butter prices, and that by August "spot" quotations have advanced to 26c. The dealer now decides to use this car that he has sold for November delivery, in his own business, where he can sell it at a good profit. This, then, leaves him without a car for November delivery. In order to satisfy his "futures" contract, he must, therefore, purchase another similar car to fulfill his contract. This he should do at once in order to square his transactions with the Exchange. He may, however, defer purchase of the required car, anticipating a lower market later when he expects to be able to buy in at a more favorable price.

The "Hedge".—The instrument by which trading in "futures" is accomplished is called the "Hedge." Hedging is undeniably speculative. However, the elements of speculation are present in most transactions that involve the holding of butter for future use, such as when the dealer who buys butter, puts it in storage, anticipating sale at a later date at a price sufficiently favorable to cover the original cost, carrying charges and a margin of profit. The same applies in the case of the creamery that stores its butter for similar purposes.

Trading in contracts for future delivery, or "hedging," assists the creamery or the dealer in making disposition of surplus butter at a time when the market is oversupplied or glutted, and satisfactory outlets may be limited. Likewise, the use of the "hedge" assists the dealer who must accumulate large stocks seasonally, for sale when production is seasonally low, in protecting him against excessive losses on his inventories, that might occur due to changing prices. The risk in such case is transferred from owner to speculator, or to another dealer.

The term "Hedge" applies to all trading in "futures" in which the seller is in possession of the butter at the time the contract is made. "Futures" contracts are also negotiated without possession of the butter. Such contracts are not covered by

the definition of the "hedge." They are purely speculative, dealing exclusively with "short" sales.

Relation of "Spot" Price to "Futures" Price.—By "Spot" price is understood the price quotation on the Mercantile Exchange of butter sold for immediate delivery. Selling butter on a "futures" contract requires consideration of the relationship between "spot" and "futures" prices. As previously stated, the primary incentive of "hedging" lies in the expectation on the part of the buyer and seller, of a favorable trend of prices between the time of entering the contract and the time of its termination.

The margin between June "spots" and November "futures" is not a fixed one. It may vary widely according to many conditions; such as relation of supply and demand, status of storage holdings, the banking situation that controls the money available for storage, speculative demand, elasticity of supply and demand, etc. Sprague and Foelsch[3] define an elastic supply as one which responds quickly to small price changes, and an elastic demand as one when small changes in price are accompanied by proportionately large changes in amounts purchased. They further point out that the price of butter cannot be maintained at a level which throws production and consumption out of adjustment for a long time, without causing adjustments in storage stocks. They summarize the relationship of "spots" to "futures" as follows:

"When the 'spot' price is below the 'futures' by 1¼ to 1½ cents, the cost of storage is covered and the owner of butter can 'hedge' and hold his butter with little risk. When the spread is greater than 1½ cents, the owner of butter can store with a profit. When the spread is less than 1¼ cents the risk is not all removed and the storer of butter must hope for a more favorable adjustment of the spread between 'spot' and 'futures' prices at a later date, in order to make a profit." The above conception of relationship between "spot" and "futures" prices, is in agreement with commercial experience in trading for future delivery.

Butter Exchanges.—The butter exchange is a voluntary trade organization of wholesale dealers in butter. In many cases the Exchange is not confined to butter alone, but includes other allied commodities as well, such as cheese, eggs, poultry, etc. The produce exchanges generally are incorporated associations. Specific examples of produce exchanges for butter, or butter

and allied produce, whose operations are recognized as having the greatest influence upon the marketing of butter in this country are:

The New York Mercantile Exchange, New York, N. Y.

The Chicago Mercantile Exchange, Chicago, Ill.

The San Francisco Wholesale Dairy Produce Exchange, San Francisco, Calif.

The Boston Chamber of Commerce, Boston, Mass.

The specific objects and functions of the different exchanges cover a wide field of endeavor. Weld[2] enumerates the primary functions of the produce exchange as follows:

1. To provide a convenient market for trading.
2. To regulate business dealings of members.
3. To provide a system to facilitate the settlement of trade disputes.
4. To establish uniform grades and a system of inspection.
5. To acquire and to disseminate market information.

The "Call".—One of the important features of the butter exchange is the "call", also called the "spot call." Weld defines the "call" as a "device for making bids and offers, partly to establish market prices or quotations, and partly to bring about actual sales."

The "call" is usually conducted in a room of the Mercantile Exchange, equipped with blackboard on which are recorded receipts of the day, offers and bids made under the call, and general market conditions, and other important information such as score, package, and place of delivery. After the offers for sale, including information as to quality, score and price, made by the traders, are posted on the board, bids are called for. The bids are also posted. The members of the Exchange appear on the floor, and buyers and sellers make public bids on the offers of butter. Often these offers and bids result in sales, and these sales show in public the prices at which receivers are willing to sell their butter, and the prices at which buyers are willing to purchase it. It is from these postings that market quotations are made.

The bidding under the "call" affords competitive sellers an opportunity to sell butter against each other according to the supply. Should there be a greater demand for butter on any one day at a price above the quotation of the previous day, the quo-

tation will be advanced to such a point as buyers are paying for the butter, for the buyers will not stand for any quotation that is lower than the price they are actually paying for butter. The same principle applies to the sellers. Should the sellers be loaded down with butter, it is their privilege to offer it at prices at which and until the buyers will take hold, and often-times with the market stocked with butter, it is necessary to sell it at prices where the retailers will be able to reduce their selling price to the consumer. In this way the consumer becomes interested in consuming more butter and the surplus stock becomes disposed of.

When there are no sales under the "call," a situation which occurs not infrequently, the quotations of the previous day remain in effect. However, an unaccepted bid places a lower limit on the price quotation, as it indicates willingness to buy at a price, while an offer sets the upper limit, as it indicates a willingness to sell.

The actual sales and purchases made under the "call" are usually few, and the volume so traded represents only a small percentage of the daily receipts of butter, often averaging not more than five per cent. The predominating tendency of the butter trade appears to be toward conducting its transactions through the medium of private sales. In adjusting their surpluses, wholesale receivers prefer to trade directly with each other, rather than conduct their transactions under the "call." When using their own facilities they eliminate the charges for the services of the "call" board, and the charges for the inspection and for the official inspection certificate, inspection by the Exchange being required when trading under the "call."

The "call," however, does serve in many instances as a convenient means for the seller who has a surplus, to find a buyer, and for the buyer in case of shortage of any particular grade of butter, to locate a seller of that grade. Also in those cases where, accidentally, a lot of butter is graded with a score above that with which grades for other buyers are likely to agree, a sale under the "call" may become the most desirable method of transfer, since the grading certificate is the only evidence of quality and provides the dealer with a better opportunity to get a higher price for his butter. Considerable trading also is usually done privately between members at the conclusion of the "call" and before the meeting adjourns.

Butter Quotations.—The problem of determining butter quotations is a subject of the greatest importance to the entire butter industry. Butter quotations, in order to be correct, should coincide with the actual market value of the butter. They should therefore be based on the supply and demand of butter, as otherwise they may cause serious disturbances in the normal movement of butter on the market, which disturbances would tend to operate against the best interests of the butter business.

Formerly the New York and Chicago quotations were determined by a committee of the New York Mercantile Exchange and the Chicago Mercantile Exchange, respectively. These committees, consisting of dealers who were in most intimate touch with the market and with the actual market value of the butter, were assumed to be admirably qualified to arrive at just and correct quotations. They met each day at the conclusion of the "call" behind closed doors.

"This same practice obtained abroad, and in Denmark butter quotations decided upon by the Copenhagen merchants are still largely used as a basis of settlement with creameries. But in this country quotations made by price committees of merchants have not been looked upon with favor by government officials, especially when they did not accurately represent prevailing values. It was usually found that the tendency of most price committees of merchants was to keep the official quotations below prevailing selling values.[4]"

In 1907 the Mercantile Exchange of New York was sued by the government on the ground of fraudulent manipulation of quotations which resulted in the exchange being prohibited from issuing quotations not representing the value of butter based on actual sales by first hand receivers. In a decision rendered by the Supreme Court it was decided that this quotation committee was a combination in restraint of trade and the practice was declared illegal. Realizing that actual sales under the "call" of the exchange were too small to justify basing quotations on such sales, the exchange discontinued the issuance of official quotations and the determination of price quotations was assumed by outside market reporters.

Since then the firm of Urner-Barry Company, with the help of a most efficient force of trained market reporters, has assumed the responsibility of establishing daily price quotations in New York. After the "call" each day, having taken into con-

sideration the bids and offers under the "call," the market reporter makes a canvass of the market, calling on the buyers and sellers, and ascertains the prices at which they are doing business through private negotiations; then, at about noon each day he announces the quotations he will publish in his paper for the various grades of butter. These quotations are accepted as the settling basis for the day, and they are the quotations that are sent broadcast throughout the country.

In Chicago the quotation committee met a similar fate, the courts prohibiting its functions, unless quotations were made on the basis of actual sales, and thus the making of butter quotations passed into the hands of outside market reporters.

Beginning with January 1st, 1939, butter prices at Chicago are being quoted by two agencies. Trading on the "spot call" each morning at the Chicago Mercantile Exchange is quoted by the market price reporter of the Chicago Produce Publishing Company. This price is quoted immediately after the "call" at about 10 o'clock and tends to become the basis for trading during the remainder of the day. Shortly after noon the market is again canvassed and quoted by a representative of the U. S. Bureau of Agricultural Economics at about 3 o'clock. This later quotation, and the comments which accompany it, reflect the extent to which the morning quotation has been supported by trading later in the day.

It is obvious that the market reporter, in assuming the responsibility of making price quotations, is thus vested with vast powers, the abuse of which for personal interests, or through incompetence, would throw the market into a most chaotic condition. The market reporter must therefore, be a man of ability, experience and judgment. He secures his information by canvassing the trade and must be able to distinguish between gossip and facts, and between fiction and the truth. In addition to the general problem of supply and demand, he must cope with the influence of the storage butter demand and supply on the market value of fresh butter. He must above all be a man of superior integrity and honesty, and he must be unbiased.

RULES THAT GOVERN THE "SPOT CALL"

Butter sold at the "spot call" must conform to the rules of the Mercantile Exchange. While these rules differ somewhat in details between the various Exchanges, they are very similar in

principle. In the case of the Chicago Mercantile Exchange, the more important rules for the purpose of price quotations are summarized by Sprague and Foelsch,[3] as follows:

"1. All lots are sold subject to quality verification by inspectors of the Chicago Mercantile Exchange.

"2. Delivery is made at the point of inspection, either in a car on track, or in the approved cooler of a member dealer's place of business.

"3. No sale is in an amount less than 50 tubs.

"4. Butter must be fresh, unless otherwise specified.

"5. Delivery must be made in new tubs, unless otherwise specified.

"6. Payment must be made within a specified time, subject to penalities for failure of either buyer or seller to complete his contract."

Price Differentials.—The principal function of the price quotation is its use as a price basis. In general, butter is purchased or sold either at some previously quoted price, or at some fraction of a cent above or below it. Regardless to whom the creamery sells its butter, whether local sales for home consumption, or to a chain store organization, or to the operator of a concentration point, or to a wholesale receiver at some central market, its sales are generally based on some wholesale market quotation, with a suitable differential above or below the quotation. These price differentials for the same grade of butter, once agreed upon between seller and buyer, are usually of fairly stabilized uniformity.

The main exception to the functioning of a definite differential price structure occurs in the case of the retailer's sales to the consumer, as evidenced by the wide variations of the "mark-up" by the retailer to the consumer. As a result of the disregard on the part of the average retailer, of a uniform differential price structure, the range in prices paid by consumers at retail stores is much wider than the range in prices at wholesale.

Aside from the factor of bargaining ability of individuals engaged in buying and selling, differentials may be based on such factors as type of package, transportation charges, quality and variations of individual scores. Sprague and Foelsch[3] point out further that "if the quotation tends to represent the average value of the grade, creamery sales agreements should be mostly

below the quotation, because the sales agreements represent outright purchases by receivers, whereas quotations represent their sales. Dealers estimate their costs at from ¼ to ½ cents per pound; therefore, they should buy their butter at differentials averaging about ¼ to ½ cents below the quotation, if it represents the price at which they sell.

Premiums.—Premiums of ¼ to ½ cents above market quotation paid to creameries are a common occurrence. In exceptional cases premiums as high as 1 and 2 cents are being paid. The fundamental basis upon which premiums are paid in marketing, is that of compensation for exceptionally desirable characteristics in a product. In the case of butter, such factors as better than average quality within the grade, exceptional uniformity of quality, superior workmanship, reputation for keeping quality, a volume sufficient to deliver large lots at regular intervals, are considered characteristics meriting premiums. In short, premiums are generally associated with butter of better than average characteristics. On a similar basis, discounts should be, and usually are, made in the marketing of commodities of less than average desirable characteristics.

The possibility that what is considered as a premium may at times be only an adjustment in price to reflect the average for the grade, suggests that in such cases the so-called premium merely represents a price correction of an under-quoted market, as pointed out by Sprague and Foelsch.[3] But even if such is the case, it is only the product with better than average characteristics within the grade, on which the upward price adjustment, or so-called premium operates.

Grades and Standards for Quality of Butter.—Prior to April 1st, 1939, the same general standards, grades and scores of butter were promulgated and used by the various Mercantile Exchanges in the principal markets throughout the country. Minor differences excepted, the Definitions and Classifications of the New York Mercantile Exchange, revised to June 1, 1937, and now in force (January 1, 1940), are representative of these standards and scores of quality. They are given in succeeding paragraphs. On April 1, 1939, the "Official United States Standards for Quality of Creamery Butter, promulgated November 3, 1938 and effective April 1, 1939, were adopted by the Chicago Mercantile Exchange, and also by the San Francisco Wholesale

Dairy Produce Exchange. These New Standards are given in full in later pages.

DEFINITIONS, GRADES AND SCORES OF CREAMERY BUTTER OF THE NEW YORK MERCANTILE EXCHANGE

(by Courtesy of Urner-Barry Co., New York)[5]

Grades.—Creamery Butter shall be graded as Extras, Standards, Firsts, Seconds and Thirds. Creamery Butter, salted or unsalted, of a score higher or lower than required, may be offered and bid for by score.

SALTED BUTTER

EXTRAS.—Shall be a grade of average fancy quality in the season when offered under the various qualifications and shall conform to the following standard:

Flavor must be sweet, fresh and clean for the season when offered.

Body must be reasonably firm and reasonably uniform.

Color not higher than natural grass, nor lighter than straw, but must not be streaked or mottled.

Salt, medium salted.

Package, New, sound, uniform, and clean.

Extra Creamery may score either 91, 92 or 93 points at the discretion of the Butter Committee, who shall determine the required score from time to time in such manner that it shall represent an average fancy quality in the season when offered. But butter scoring more than required for Extras shall be deliverable on a contract for Extras, and may be branded as such at the request of seller or buyer. Any change in the score required for Extras shall, after authorization by the Butter Committee, be announced by the caller at the opening of the next regular call and posted upon the bulletin board of the Exchange and be effective 24 hours later.

STANDARDS.—Carlots of butter classified as Standards, shall be butter manufactured in one creamery, and shipped in carlots, and shall score 90 points.

FIRSTS.—Shall be below Extras, scoring 91 to 88, inclusive. Must be good butter when made and offered under the previous classifications and shall conform to the following standards:

Flavor must be reasonably sweet, reasonably clean, and fresh.

Body must be reasonably firm, and fairly uniform.

Color reasonably uniform, neither very high nor very light, and neither streaked nor mottled.

Salt may be reasonably high, light, or medium.

Package, new, sound, and reasonably clean.

The minimum score of Firsts shall, at all times be 4 points below the score required for Extras.

SECONDS.—Shall be grades next below Firsts and scoring from 87 to 84 inclusive, and shall conform to the following standards:

Flavor must be reasonably good.

Body. If Creamery, must be reasonably solid boring.

Color. Fairly uniform, but may be mottled or streaky.

Package. Good and uniform.

The minimum score of Seconds shall be 4 points below the minimum score required for Firsts.

THIRDS.—Shall be a grade below Seconds and may consist of promiscuous lots, and shall conform to the following standards:

Flavor. May be off-flavored, and strong on tops and sides.

Body. Not required to draw full trier.

Color. May be irregular, or mottled.

Salt. High, light, or irregular.

Package. Any kind of package mentioned at time of sale.

The minimum score of Thirds shall be 7 points below the minimum score required for Seconds.

Scoring.—The standard official score shall be as follows and shall apply to salted Creamery Butter only.

Flavor	45 points
Body	25 points
Color	15 points
Salt	10 points
Style	5 points
	100 points

UNSALTED CREAMERY BUTTER

EXTRAS.—Shall be a grade of average fancy quality in the season when offered, under the various classifications and shall conform to the following standard:

Flavor. Must be sweet, fresh, clean for the season when offered.

Body. Must be reasonably firm, and reasonably uniform.

Color. May be very light straw, white, or natural grass, but must not be streaked or mottled.

Package. New, sound, uniform, clean.

FIRSTS.—Shall be grades next below, scoring 91 to 88 inclusive, must be good butter for the season when made and offered under the various classifications, and shall conform to the following standard:

Flavor. Must be reasonably sweet, reasonably clean, and fresh.

Body. Must be reasonably firm, and fairly uniform.

Color. May be very light straw, white, or natural grass, but must not be streaked nor mottled.

Package. New, sound, uniform, and reasonably clean.

SECONDS.—Shall be grades next below Firsts, and scoring from 87 to 84 points, inclusive, and shall conform to the following standard:

Flavor. Must be reasonably good.

Body. Must be solid boring.

Color. Fairly uniform, but may be mottled.

Package. Good, and uniform.

THIRDS.—Shall be a grade below Seconds and may consist of various lots, and shall conform to the following standard:

Flavor. May be off-flavored and strong on tops and sides.

Body. Not required to draw a full trier.

Color. May be irregular, or mottled.

Package. Any kind of package specified at time of sale.

Scoring.—The standard official score shall be as follows, and shall apply to Unsalted Creamery Butter only:

Flavor	45 points
Body	25 points
Color	20 points
Style	10 points
	100 points

DEFINITIONS, GRADES AND SCORES OF CREAMERY BUTTER IN EFFECT AT THE CHICAGO MERCANTILE EXCHANGE, APRIL 1, 1939[6]

(By Courtesy of Lloyd S. Tenny, Bus. Mgr. Chicago Mercantile Exchange).

"All scoring of creamery butter must meet the requirements of the standards promulgated from time to time by the Secretary of Agriculture, and all inspections shall be made in accordance with such regulations."

In the place of the former terminology of grades, i.e., Extras, Standards, Firsts, etc., the U. S. Government Standards consist of numerical scores as the quality basis for sales, ranging from 93 to 85, inclusive. For the convenience of the reader the evaluation of these numerical scores relative to the old terminology of grades is briefly summarized below.

93 Score (formerly Specials)
92 Score (formerly Extras)
91 Score (formerly Extra Firsts)
90 Score (formerly Standards) in carlots
89 Score (formerly Firsts)
88 Score (formerly lower limit of Firsts)
87 to 85 Score, inclusive (formerly Seconds)
No Score (formerly Thirds, including also former 84 Score)

A detailed description of the U. S. Standards and scores, and their applications follow:

"OFFICIAL U. S. STANDARDS FOR QUALITY OF CREAMERY BUTTER[6]

Promulgated November 3, 1938; Effective April 1, 1939.
U. S. Dept. Agr., Bureau Agricultural Economics.[1]

Section 55.41 Terms Defined.—For the purpose of the United States standards[2] for quality of creamery butter:

1. Supersedes Service and Regulatory Announcements (Markets) 51.
2. The specifications of these standards shall not excuse failure to comply with the provisions of the Federal Food and Drugs Act.

(a) Butter. Butter shall be the food product usually known as butter, and which is made exclusively from milk or cream, or both, with or without common salt, and with or without additional coloring matter, and containing not less than 80 per cent by weight of milk fat, all tolerances having been allowed for.[3]

(b) Creamery butter. Creamery butter shall be butter manufactured in a commercial creamery.

(c) United States score grade. The United States score grade of a lot of creamery butter consisting of packages of the same official United States score shall be expressed in terms of an official United States score using whole numbers only. The United States score grades shall be from U. S. 85 score to U. S. 93 score, inclusive.*

Section 55.42 United States Grades for Creamery Butter.— The following United States grades for creamery butter are established:

(a) U. S. 93 score butter shall possess a fine flavor. It may possess a very slightly normal feed or slightly cooked flavor. It is made from cream to which a culture (starter) may or may not have been added. The total permitted defects in body, color, and salt are limited to a rating of one-half (tables 1 and 2).

(b) U. S. 92 score butter shall possess a pleasing flavor. It may possess a slightly normal feed, slightly storage, slightly heated cream (summer defect), slightly flat, slightly coarse-acid, or a definitely cooked flavor. The total permitted defects in body, color, and salt are limited to a rating of one-half unless the flavor rating is sufficiently high to permit the total ratings for defects in these factors to exceed one-half; provided, however, that the total ratings for defects in body, color, and salt must not exceed one in 92 score butter regardless of the flavor rating (tables 1 and 2).

(c) U. S. 91 score butter shall possess a fairly pleasing flavor. It may possess any of the following flavors if present only to a slight degree: Acidity, utensil, scorched, neutralizer, aged (butter), greasy, woody, bitter, and old-cream. It may possess any of the following flavors even when present to a definite degree: Storage, normal feed, heated cream (summer defect), flat, coarse-acid, and smothered. The total permitted de-

3. In conformity with an act of Congress approved March 24, 1923.
*Sections 55.41, to 55.48 issued under the authority contained in 52 Stat. 740.

fects in body, color and salt are limited to a rating of one-half unless the flavor rating is sufficiently high to permit the total ratings for defects in these factors to exceed one-half (tables 1 and 2).

(d) U. S. 90 score butter shall possess a fairly pleasing flavor. It may possess any of the following flavors if present only to a slight degree: Cabbage, turnip, potato, rape, weedy (ordinary-common), and musty. It may possess any of the following flavors even when present to a definite degree: Acidity, utensil, scorched, neutralizer, aged (butter), greasy, woody, bitter, and old-cream. The total permitted defects in body, color, and salt are limited to a rating of one-half unless the flavor rating is sufficiently high to permit the total ratings for defects in these factors to exceed one-half (tables 1 and 2).

(e) U. S. 89 score butter may possess any of the following flavors if present only to a slight degree: Fruity, yeasty, cheesy, oily, metallic, and barny. It may possess any of the following flavors even when present to a definite degree: Sour, scorched-neutralizer, scorched-old-cream, alkaline, cabbage, turnip, potato, rape, weedy (ordinary-common), musty, and stale-cream. The total permitted defects in body, color, and salt are limited to a rating of one unless the flavor rating is sufficiently high to permit the total ratings for defects in these factors to exceed one (tables 1 and 2).

(f) U. S. 88 score butter may possess a slightly obnoxious weed flavor or any of the following flavors even when present to a definite degree: Fruity, yeasty, cheesy, oily, metallic, cabbage, turnip, potato, rape, and barny. It may possess any of the following flavors even when present to a pronounced degree: Alkaline, musty, and stale-cream. The total permitted defects in body, color, and salt are limited to a rating of one unless the flavor rating is sufficiently high to permit the total ratings for defects in these factors to exceed one (tables 1 and 2).

(g) U. S. 87 score butter may possess a fishy, onion and garlic flavor if present only to a slight degree. It may possess an obnoxious weed and barny flavor even when present to a definite degree. It may also possess a yeasty and cheesy flavor when present to a pronounced degree and a stale-cream flavor when present to a very pronounced degree. The total permitted defects in body, color, and salt are limited to a rating of two unless

the flavor rating is sufficiently high to permit the total ratings for defects in these factors to exceed two (tables 1 and 2).

(h) U. S. 86 score butter may possess any of the following flavors: Definitely fishy, definitely onion or garlic, and pronouncedly obnoxious weeds. The total permitted defects in body, color, and salt are limited to a rating of two unless the flavor rating is sufficiently high to permit the total ratings for defects in these factors to exceed two (tables 1 and 2).

(i) U. S. 85 score butter may possess a pronouncedly obnoxious weed, onion and garlic flavor. The total permitted defects in body, color, and salt are limited to a rating of three unless the flavor rating is sufficiently high to permit the total ratings for defects in these factors to exceed three (tables 1 and 2).

(j) No grade. Butter that is below the requirements of U. S. 85 score because of its flavor or other conditions or because of excessive defects in body, color, and/or salt shall be classified as "no grade."[4]

Section 55.43 Basis for Determination of Quality of Creamery Butter.—The basis for determination of quality of creamery butter, except "no grade" butter, shall be the ratings given the flavor and the defects in body, color, and salt. The official United States score of individual samples of creamery butter shall be determined by the following general rule:

General Rule: The official United States score of an individual sample of creamery butter shall be determined by deducting from the flavor rating[5] of the sample the amount that the total ratings of the defects in body, color, and salt is in excess of the ratings for defects permitted in these factors for butter of the particular flavor rating (table 1), the official United States score to be expressed as a whole number by lowering any half score to the next lower full score; provided, however, that the total ratings for defects in body, color, and salt must not exceed one in 92 score butter regardless of the flavor rating.[1]

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4. See Sec. 55.45 for flavors and conditions that cause butter to be classified as "no grade."

5. When more than one flavor is discernible in a sample of butter the flavor rating for the sample shall be established on the basis of the flavor that carries the lowest rating.

Section 55.44 Ratings of Certain Identified Flavors in Creamery Butter.—The various identified flavors in butter listed below shall be rated as follows:

Identified flavor	Rating
(a) Fine	93
(b) Pleasing	92
(c) Fairly pleasing	91-90
(d) Acidity:	
Slightly acidy	91
Definitely acidy	90
Definitely sour	89
(e) Utensil:	
Slightly utensil	91
Definitely utensil	90
(f) Fruity:	
Slightly fruity	89
Definitely fruity	88
(g) Yeasty:	
Slightly yeasty	89
Definitely yeasty	88
Pronouncedly yeasty	87
(h) Cheesy:	
Slightly cheesy	89
Definitely cheesy	88
Pronouncedly cheesy	87
(i) Cooked:	
Slightly cooked	93
Definitely cooked	92
(j) Scorched:	
Slightly scorched-acid	91
Definitely scorched-acid	90
Definitely scorched-old-cream	89
(k) Neutralizer:	
Slightly neutralizer	91
Definitely neutralizer	90
Definitely scorched-neutralizer	89
Definitely alkaline	89
Pronouncedly alkaline	88
(l) Storage:	
Slightly storage	92
Definitely storage	91

(m) Aged (butter):
- Slightly aged 91
- Definitely aged 90

(n) Greasy:
- Slightly greasy 91
- Definitely greasy 90

(o) Oily:
- Slightly oily 89
- Definitely oily 88

(p) Metallic:
- Slightly metallic 89
- Definitely metallic 88

(q) Fishy:
- Slightly fishy 87
- Definitely fishy 86

(r) Normal feed:
- Very slightly normal feed.......... 93
- Slightly normal feed............... 92
- Definitely normal feed 91

(s) Cabbage, turnip, potato, rape:
- Slightly cabbage, turnip, potato, rape 90
- Definitely cabbage, turnip, potato, rape 89-88

(t) Weedy (ordinary-common):
- Slightly weedy 90
- Definitely weedy 89

(u) Obnoxious weeds:
- Slightly obnoxious weeds.......... 88
- Definitely obnoxious weeds 87
- Pronouncedly obnoxious weeds...86-85

(v) Onion or garlic:
- Slightly onion or garlic............ 87
- Definitely onion or garlic.......... 86
- Pronouncedly onion or garlic....... 85

(w) Musty:
- Slightly musty 90
- Definitely musty 89
- Pronouncedly musty 88

(x) Woody:
- Slightly woody 91
- Definitely woody 90

(y) Heated cream (summer defect):
  Slightly heated cream 92
  Definitely heated cream............ 91
(z) Flat:
  Slightly flat 92
  Definitely flat 91
(aa) Coarse:
  Slightly coarse-acid cream......... 92
  Definitely coarse-acid cream........ 91
(bb) Smothered:
  Definitely smothered 91
(cc) Bitter:
  Slightly bitter 91
  Definitely bitter 90
(dd) Old-cream:
  Slightly old-cream 91
  Definitely old-cream 90
(ee) Stale-cream:
  Definitely stale-cream 89
  Pronouncedly stale-cream 88
  Very pronouncedly stale-cream 87
(ff) Barny:
  Slightly barny 89
  Definitely barny 88-87

Section 55.45 Flavors and Conditions in Butter That Cause It To Be Classified as "No Grade."—Butter that possesses the following flavors or in which the following conditions are present shall be classified as "No Grade":

(a) Flavors:
  Pronouncedly fishy
  Surface-taint
  Limburger
  Tallowy
  Rancid
  Paint or varnish
  Gasoline, kerosene or fly spray
  Chemical
(b) Conditions:
  Mold
  Grains of sand

Splinters of wood
Specks of rust
Other foreign materials*

Section 55.46 Ratings for Defects in Body, Color, and Salt.—The ratings for defects[6] in body, color, and salt shall be established in accordance with the following rules:

Rule (a) Gummy, leaky, spongy or weak, crumbly, or sticky body, wavy color, color specks and sharp salt shall be rated for defects as follows:

Defects	Rating
Slight	½
Definite	1

Rule (b) Ragged-boring, mealy or grainy, and streaked or mottled color shall be rated for defects as follows:

Slight	1
Definite	2

Rule (c) High color (unnatural) shall be rated for defects as follows:

Pronounced	1

Rule (d) Gritty salt shall be rated for defects as follows:

Slight	1
Definite*	2

Section 55.47 Defects Permitted in Body, Color, and Salt Without Causing Official United States Score to Be Placed Below Flavor Rating.—The maximum total ratings for defects in body, color, and salt permitted in butter that do not cause the official United States score of butter to be lowered below the flavor rating are indicated in Table 1.

Table 1

Flavor Ratings	Maximum Total Ratings for Defects Permitted in Body, Color, and/or Salt:	Limitations of Defects to 1 or More Factors
93	½	In 1 factor only
92	½	In 1 factor only
91	½	In 1 factor only
90	½	In 1 factor only
89	1	....
88	1	....
87	2	....
86	2	....
85	3	....

[6]See table (Sec. 55.47) for ratings of each degree of defect in body, color, and salt.

When the sum of the ratings for the defects in body, color and salt exceeds that permitted by Table 1 for butter of a specified flavor rating, the butter shall be given an official United States score below the flavor rating in accordance with the general rule (Sec. 55.43), for determining the official United States score of individual samples of creamery butter.

Section 55.48 Application of General Rule.

Table 2
Examples Illustrating Application of General Rule

Example No.	Flavor Rating	Defects Present in			Total Defects Present	Defects Permitted	Defects in Excess of Those Permitted	Official U. S. Score
		Body	Color	Salt				
1	93	½	0	0	½	½	0	93
2	93	0	1	0	1	½	½	92
3	93	½	1	0	1½	½	1	91[1]
4	92	0	½	0	½	½	0	92
5	92	0	1	0	1	½	½	91
6	91	0	1	1	2	½	1½	89
7	90	1	0	0	1	½	½	89
8	89	½	½	0	1	1	0	89
9	89	1	1	0	2	1	1	88
10	88	0	2	1	3	1	2	86
11	87	2	1	0	3	2	1	86
12	87	2	2	0	4	2	2	85
13	86	1	2	0	3	2	1	85
14	85	2	2	0	4	3	1	[2]

[1]See explanation of example 3 below for detailed information.
[2]"No grade."

Examples 1, 4, and 8 are given an official United States score which is the same as the flavor rating because the defects in body, color, and salt are not in excess of those permitted in butter of the particular flavor rating. The official United States score of all other samples is lower than the flavor rating because the defects in body, color, and salt exceed those that are permitted in butter of the particular flavor rating, the excess being in the amount of one-half or more.

In example 2, the flavor rating is 93. The defects permitted in body, color, and salt for butter of that flavor rating are limited to a maximum of one-half. The defects present in the sample amounted to 1, therefore the defects are in excess of those permitted by a total of one-half. The official United States score is lowered 1 below the flavor rating instead of one-half because the official United States score must be expressed as a whole num-

ber. In example 3, the official United States score is lowered 2 below the flavor rating instead of 1 because the total ratings for defects in body, color, and salt must not exceed one in 92 score butter. In example 10, the flavor rating is 88. The permitted defects in body, color, and salt for butter with a flavor rating of 88 are 1. The defects in this particular sample totaled 3 and are, therefore, in excess of those permitted by a total of 2. The official United States score, therefore is 2 lower than 88 or 86. In example 14, the flavor rating is 85. The total permitted defects in body, color, and salt for butter with a flavor rating of 85 is 3. This butter showed defects totaling 4, or 1 in excess of those permitted in butter with a flavor rating of 85. The official United States grade of this butter is indicated by "no grade" because the application of the general rule would give this butter a score of 84. Such butter is below the requirements of U. S. 85 score because of excessive defects in body, color, and salt. Therefore, it must be classified as 'no grade.'"

Inspection and Grading.—Upon its arrival in the wholesale receiver's hands, the butter is inspected and graded on the basis of the standard scores or grades recognized by the wholesale produce trade of the market in their locality. Most wholesale receivers have their own private butter graders who perform this work.

The butter exchanges in the larger markets maintain a force of inspectors who inspect butter for members of the Exchange, upon application made in accordance with the rules of the Exchange, for which an Official Inspection certificate is issued.

The official inspection certificate of the Chicago Mercantile Exchange states the location of the commodity, grade established, date of inspection, time when the certificate expires, and brands, if any. It bears the signature of the Chief Inspector or, in his absence, of the Business Manager, or the Assistant Business Manager, and the seal of the Exchange. This certificate is final. In addition it contains a detailed report of the findings of the inspection, except when the Chicago Mercantile Exchange certificate is based upon an inspection certificate of the U. S. Government, in which case such Government certificate or copy thereof, accompanies the Mercantile Exchange certificate.

The Chicago Exchange Rules on inspection and weighing of butter require that one package of each churning in each

lot, and at least 5% of each lot, must be inspected. An inspection certificate of quality or weights on butter in store or on track is valid until 5:00 P. M. of the fourth calendar day after the day on which the butter is inspected, providing that, in all cases, the butter has been kept under proper refrigeration. Inspection certificates on butter in cold storage are valid for longer periods, depending on the time of the season when inspections are made. Similar rules govern the inspections and issuance of official inspection certificates made by other Mercantile Exchanges.

The great bulk of butter shipped to the wholesale receiver of the larger markets is not subjected to inspection by the official inspector of the Mercantile Exchange. Sales, on the negotiations of which official inspection is not requested nor made, are commonly spoken of as being "over the trier." The inspection service maintained by the Exchange is largely, if not entirely made on those lots of butter for which inspection is requested by the buyer, when purchased under the "call," as for instance in case of dispute between seller and buyer as to grade, or when butter is sold to the Government.

Trend of Butter Marketing Systems.—It was shown in the foregoing discussion that a large portion of the Country's annual butter production reaches the consumer through the channels of the wholesale produce trade, i.e., from creamery to wholesaler, to jobber, to retailer, to consumer. The institution of the wholesaler-jobber thus is an independent, specialized agency, performing the functions of assembly, grading and standardization, demand creation, sale, financing, and risk-bearing.

During the post-war period, forces were at work that caused the scope and type of institutions capable of performing these functions to expand and this expansion operated in the direction of direct marketing, through integration from manufacturer to retailer.

Thus the rapid growth in scale and in financial resources of the centralized creamery, with its demand creation through established private brands and market control, and its success of quality standardization through laboratory control; the entrance of the packers in the field of butter manufacture, with their extensive systems of distribution; the formation of large co-operative sales organizations with distribution centers in

the large markets; and the accelerated growth and activities of chain store organizations combining buying direct from country plants, with wholesale and retail functions, have constituted powerful factors in the growing trend toward direct marketing of butter, through co-ordinating specialization under one management.

The forces associated with and responsible for these changes, and their influence on the future trend of butter marketing, have been extensively studied and are ably discussed by Nicholls.[7]

Exports and Imports

In spite of the fact that the United States produces over twice as much butter annually as any other single country, its international trade in butter is negligible in volume. Its extensive home markets absorb practically its entire output and its large annual production is sufficient to take care of its needs.

The butter exports from the United States go largely to the Honduras, Panama, the West Indies, exclusive of Bermuda, and to the Philippine Islands. The imports of butter into the United States, while small, vary considerably with the price difference between the home market and the London market. The bulk of the butter imported usually comes from such countries as the Netherlands, the Baltic States, New Zealand, the Argentine, and

Table 43.—Exports and Imports of Butter for the United States 1911-1936*

Year Beginning July	Exports Pounds	Imports Pounds	Year Beginning July	Exports Pounds	Imports Pounds
1911	6,092,000	1,026,000	1924	8,384,000	7,189,000
1912	3,586,000	1,162,000	1925	5,280,000	6,440,000
1913	3,694,000	7,842,000	1926	5,048,000	10,710,000
1914	9,851,000	3,828,000	1927	3,965,000	4,955,000
1915	13,487,000	713,000	1928	3,778,000	3,299,000
1916	26,835,000	524,000	1929	3,582,000	2,851,000
1917	17,736,000	1,806,000	1930	2,293,000	1,329,000
1918	33,740,000	4,131,000	1931	1,578,000	1,838,000
1919	27,156,000	20,771,000	1932	1,386,000	991,000
1920	7,829,000	34,344,000	1933	1,416,000	763,000
1921	7,512,000	9,551,000	1934	761,000	22,393,000
1922	9,410,000	15,772,000	1935	1,098,000	5,855,000
1923	5,425,000	29,466,000	1936	840,000	14,786,000

*U. S. Dept. Agr. Year Book 1938.

occasionally from Denmark and the United Kingdom. The tota exports from, and imports into the United States for the years 1911-1936 are shown in Table 43.

The movement of butter in international trade is recordec graphically in Fig. 101. This graph shows that the leading butter exporting countries, in the order of their magnitude, are Denmark, New Zealand, Australia, the Netherlands and the Baltic States. Of the countries importing butter the United Kingdom leads by a wide margin, followed by Germany.

International Trade in Butter—Principal Countries 1937[1]

Exporting	Pounds
Denmark	337,000,000
New Zealand	327,000,000
Australia	183,000,000
Netherlands	119,000,000
Estonia, Latvia, Lithuania	105,000,000
Sweden	52,000,000
Eire	43,000,000
U.S.S.R.	32,000,000
Finland	31,000,000
Argentina	19,000,000
Poland	18,000,000
Hungary	13,000,000

Million Pounds: 100 200 300

Millions Pounds: 900 200 100

Importing	Pounds
United Kingdom	941,600,000
Germany	166,242,000[2]
United States	14,786,000[2]

[1]From New Zealand Official Year Book 1939.
[2]For 1936. From U. S. Dept. Agr. Year Book 1938.

Fig. 101.

Import Duty.—The tariff on butter and other dairy products imported into the United States is as follows:*

Fresh milk	6½	cents per gallon
Sour milk and buttermilk........	2.2	cents per gallon
Fresh cream	56.6	cents per gallon
Butter	14	cents per pound
Casein	5½	cents per pound

Butter Prices Paid on the World's Leading Markets.—The wholesale butter prices paid for 92 score American butter in New York, Chicago, Philadelphia, Boston and San Francisco, for Danish butter in Copenhagen and London, and for New Zealand butter in New Zealand and London during the years 1928-1937 are shown in Table 44. This table gives the average price for each year. It also records the lowest and the highest average price per month.

*Effective since June 18, 1939.

Table 44.—Yearly Average Wholesale Butter Prices in New York, Chicago, Philadelphia, Boston, San Francisco, London, Denmark, New Zealand 1928-1937*

Year	American 92 Score Butter Sold in					Danish Export Butter Sold in		New Zealand Butter Sold in	
	New York Cents	Chicago Cents	Philadelphia Cents	Boston Cents	San Francisco Cents	Copenhagen Cents	London Cents	New Zealand Cents	London Cents
1928	47.40	46.00	48.39	47.54	......	38.00	40.50	37.10	37.7
1929	45.01	43.78	45.95	45.34	45.71	36.60	39.30	37.80	37.3
1930	36.51	35.28	37.49	36.91	36.31	29.70	32.30	30.20	28.0
1931	28.31	27.05	29.31	28.77	28.13	23.70	26.10	23.10	22.8
1932	21.00	20.07	22.00	21.59	21.98	15.20	18.50	15.80	15.9
1933	21.66	20.79	22.59	22.47	21.11	14.90	19.70	15.20	15.4
1934	25.70	24.78	26.71	26.59	25.05	16.40	22.10	16.90	16.4
1935	29.79	28.81	30.77	30.61	30.13	19.10	24.60	20.50	19.9
1936	33.05	32.05	33.67	33.62	33.61	20.80	26.50	22.40	22.4
1937	34.39	33.24	34.92	34.87	34.54	22.50	28.10	23.20	24.5
Highest Month	50.57	49.22	51.55	50.24	48.65	42.20	44.60	39.10	39.6
Lowest Month	16.99	16.29	17.99	17.64	17.92	10.80	14.90	11.00	10.9

*U. S. Dept. Agr. Year Book 1938.

Butter Consumption Per Capita

Available Statistics showing the per capita consumption of butter in different countries are given in Table 45. The countries are listed in the order of their butter consumption during the latest year (1937) for which complete records are available.

Table 45.—Estimated Per Capita Consumption of Butter in Different Countries*

Country	1937 Lbs.	1936 Lbs.	1935 Lbs.	1934 Lbs.	1933 Lbs.	1932 Lbs.	1931 Lbs.
New Zealand	40.7	47.3	41.2	44.3	44.0	42.7	43.0
Australia	34.2	32.4	32.8	30.8	31.1	29.3	29.0
Canada	32.7	32.3	31.8	31.1	30.2	30.5	30.8
United Kingdom	24.8	25.0	25.2	25.2	23.5	21.6	20.9
Southern Rhodesia[1]	22.7	22.7	21.2	20.6	21.5	20.2	21.3
Union of South Africa[2]	21.2	19.9	17.0	15.4	15.7	15.9	16.1
Germany	19.6	18.7	17.2	17.2	17.2	16.5	17.2
Denmark	17.9	20.1	20.7	20.1	21.2	18.7	14.9
Belgium	17.9	17.6	18.1	19.0	20.3	22.9	22.2
United States of America	16.7	16.6	17.3	18.3	17.9	18.3	18.1
Switzerland	15.0	15.0	15.2	15.7	13.9	14.3	14.3
France	12.6	12.9	12.7	12.7	12.0	11.8	12.0
Netherland	12.1	12.4	13.8	15.9	16.7	19.0	16.0
Argentina	3.9	3.9	3.8	3.8	3.4	2.1	2.5

[1]Non-natives only.
[2]Europeans only.

The above table shows that the butter producing Dominions of the British Empire lead all other countries (listed) in per capita consumption of butter.

Butter Consumption in the United States.—Table 45A indicates that the per capita butter consumption in the United States falls short by a wide margin of that of the great butter producing Dominions of the British Commonwealth. In the United States it has been fluctuating irregularly, from the beginning of available records (1849), to the present day, between approximately 14 and 20 pounds per capita per year. There has been no consistently sustained increase and even today it hovers around between 17 and 18 pounds.

In any consideration of the official records of per capita consumption of butter in the United States, we must recognize the fact that these records would probably show averages materially

*From Report of Imperial Economic Committee, Dairy Produce H.M.S. Office, London, 1938 (by Courtesy of O. E. Reed, Chief Bureau Dairy Industry, U. S. Dept. Agr.)

Table 45A.—Butter Consumption per Capita in the United States 1849-1938

Year[1]	Pounds Per Capita	Year[1]	Pounds Per Capita	Year[1]	Pounds Per Capita	Year[2]	Pounds Per Capita
1849	13.9	1916	15.4	1924	17.38	1932	18.3
1859	15.1	1917	14.6	1925	17.39	1933	17.9
1869	13.7	1918	14.0	1926	17.76	1934	18.3
1879	15.8	1919	14.8	1927	17.49	1935	17.3
1889	19.5	1920	14.7	1928	17.12	1936	16.6
1899	19.9	1921	16.1	1929	17.29	1937	16.7
1909	18.0	1922	16.5	1930	17.30	1938	16.9
1914	17.0	1923	17.0	1931	18.10	1939	17.7[3]

[1]Pirtle, T. R.: A Handbook of Dairy Statstics (1933).
[2]Dairy Situation, U. S. Dept. Agr., B. A. E. Bull. B590 (1939).
[3]Bur. Agr. Econ. U. S. D. A., by correspondence 1940.

higher for the more completely Americanized population than the statistics show, the reported averages being depressed by the status of vast numbers of consumers of foreign extraction who have not as yet been sufficiently absorbed into our system to enjoy the average standard of living of the country of their adoption. This fact is significant particularly in a comparison with New Zealand which leads the World in per capita consumption of butter and whose population is almost exclusively (95%) of English extraction.

A study of the possible reason or reasons for the mediocre volume of per capita consumption in the United States and the persistent absence of a consistent growth in our consumption of butter suggest that the lack of homogeneity of our population may be a fundamental hindrance to the accomplishment of increased butter consumption. Our complex population of emigrants from every land and race, with which our dairy industry must deal, embraces large groups of people who are racially not butter eaters. This is true especially of the people of Latin and of Slavish descent. Thus, available Government statistics show that the per capita consumption of butter in the countries of southern and eastern Europe and of Asia is below nine pounds and in some instances less than five pounds.

Furthermore, the comprehensive survey of diets in different regions of the country, made by Hazel Stiebeling and Esther Phipard[7] of the U. S. Bureau of Home Economics, shows that butter is most freely used in the North Atlantic and Pacific cities and least in the South. The average per capita consumption in a

year by white families in these three regional groups was 21, 22 and 8 pounds, respectively, indicating that butter consumption in the South is far below the national average. In addition, the Southern negro is a small butter eater. While fats are more important to him than to any other group studied, and while he averaged 70 pounds of fats and fatty foods per person per year, his per capita consumption of butter was only 7 pounds.

Increasing the Per Capita Consumption of Butter.—Regardless of regional or racial differences of diet, the problem of increasing butter consumption is obviously one of creating increased consumer acceptance of butter. Efforts along this line must inevitably deal with such essential factors as publicity relating to the merits of butter, quality of butter, and price of butter.

Publicity of the Merits of Butter.—In order for the prospective buyer to be willing to buy he must be supplied with sufficient knowledge of the merits of the merchandise to convince him that he needs and wants it. Consumer acceptance of butter, that makes for increased consumption, begins with his knowledge of the superior properties and virtues of butter, its digestibility, its nutritive qualities, its vitamin content and above all, its good flavor.

The researches of the last quarter century have revealed much new knowledge regarding the unique merits of butter fat and the great value of butter in the diet for young and old, knowledge which every consumer should have for his own physical welfare. These researches have by no means been exhausted and further investigation may have much valuable additional information to offer. Any concerted effort that will add to our fund of knowledge of the adaptability of butter to the diet, is bound to prove a valuable potential asset to the dairy industry, assisting to swell the ranks of butter eaters.

The machinery for the effective dissemination of the present knowledge of the superior functions of butter in the diet is available. Every day that the facilities of the National and Local Dairy Councils and the Dairy Union are not put to full use for publicizing butter, is a day lost in the sales calendar of the butter industry. These great institutions have been organized and are financed for the purpose of educating the consuming public and for making it milk products conscious. The efficiency of their

efforts is further augmented by the fact that the soundness of their gospel has won for them the whole-hearted support and the active co-operation of the great majority of agencies that deal with the health and with the dietary economics of the consumer, regardless of age or station in life, such as the medical profession, nurses and hospitals, school children and their teachers, parent teachers associations and extension workers, health officials and Federal and State Experiment Stations, etc. All that is needed to "cash in" on these exceptional opportunities to carry the "eat more butter" message to the masses of the consuming public, is the determined will of the industry to give these dairy publicity institutions and agencies its whole-hearted co-operation and support.

Substantiating Publicity Claims on Quality of Butter.—The importance of quality of butter in successful marketing was discussed earlier in this chapter. If publicity is to bear its potential fruit, the quality of the goods must measure up to the claims set forth. There is no denying that one of the causes of the mediocre per capita consumption of butter is attributable to the large volume of undergrades that has been reaching the great masses of consumer annually. The consumer likes butter in preference to other food fats, because of its good flavor. Flavor is the most tangible sales asset and consumer acceptance appeal of butter.

In the absence of butter of good quality the consumer may eat such undergrades as are available. He will do so to satisfy his fat requirements in the diet, but not because he relishes it. The more he tastes of it, the less he wants to eat of it. He will eat just enough of such butter to take care of his minimum fat requirements, and he will see to it that his minimum requirements further decrease. Butter made from a poor quality of farm-skimmed cream, such as butter scoring 89 points or lower, will never increase the per capita consumption, regardless of all efforts at publicizing the merits of butter.

On the other hand, good butter, such as butter scoring 92 points or better, increases consumption. The consumer relishes it and the more he tastes of it, the more he wants to eat of it. Good butter tickles his palate. He will forget to spread it, but will pile it on in chunks, not only on bread, but on every conceivable food part of the diet. The confirmed butter eater will eat more butter, and new members will be won over to the ranks

Fig. 102. National trade mark of Switzerland

CERTIFICATE OF QUALITY

Issued by Authority of the

United States Department of Agriculture

This is to certify that the churning of butter from which the butter in this package was taken was graded by an official United States Butter Grader and that the date of said grading and the number of the grading certificate issued are perforated hereon and that the quality of it when graded was

U. S. 93 SCORE

DISTRIBUTED BY

Note: To read the perforations; Read perforations from the back of certificate. First four numerals indicate number of grading certificate; the next two numerals indicate the calendar month; and the last two numerals the day of month the butter was graded.

Fig. 103. United States certificate of quality

Fig. 104. Iowa State brand

of butter eaters. Quality butter is capable of increasing the per capita consumption to record-breaking heights.

The Price of Butter and Its Relation to Per Capita Consumption.—Consumer acceptance unalterably decrees that the price of butter must synchronize with the pocketbook of the great masses of the consumer. The question is not so much one of high or low price of butter, as it is a question of relation of butter price to the price of other commodities and to the earning power of the consumer.

In general, when the price of butter is allowed to assume its natural level on the basis of the free functioning of the law of supply and demand, its tendency is to be in reasonable harmony with the purchasing power of the consumer, and it does not seriously interfere with consumer acceptance. During temporary periods of shortage in supply, and in the presence of a high import tariff, the price may rise to heights, however, that are out of line with values in general, causing butter consumption to drop.

For similar reasons, attempts at pegging the price of butter by any agency, Governmental or otherwise, in efforts to prevent it from dropping to the natural level based on supply and demand, invariably decreases consumption accordingly, and merely postpones the day of reckoning. At such times and under such conditions, but little would be gained by efforts to create consumer acceptance of butter by publicity campaigns. Attempts to maintain a high price level on a depression level income of the consumer, are the work of false prophets. Such attempts have never succeeded anywhere, for any one, at any time. They are as old as history and they have always been found wanting.

Nor should the tariff on imported butter be looked upon as a panacea for consumer acceptance at home. While a reasonable tariff assists to protect the industry against destructive competition from imported butter, an excessive tariff would react as a boomerang to butter consumption at home. A truly protective tariff need not be so high, as to boost butter prices to levels out of reach of the masses of the consuming public, and to thus discourage butter consumption. A moderate tariff that holds butter prices to a reasonable level, on the other hand, will insure maintenance of maximum butter consumption. Such a tariff, even though it may leave the door open to the importation of a lim-

National Trade Marks of Quality Butter of Some of the Butter Exporting Countries

Fig. 105. Australia

Fig. 106. New Zealand

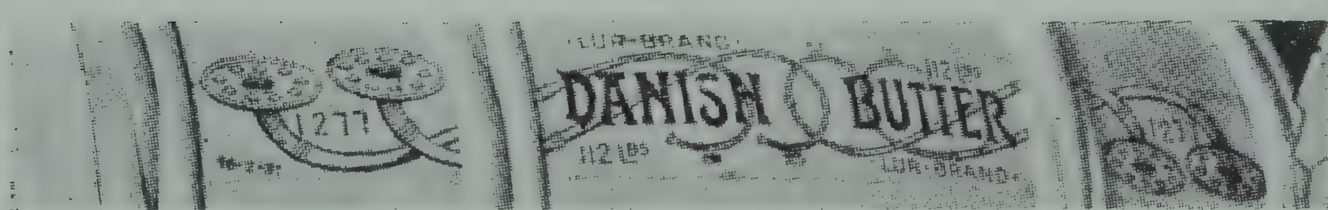


Fig. 107. Denmark

Fig. 108. The Netherlands

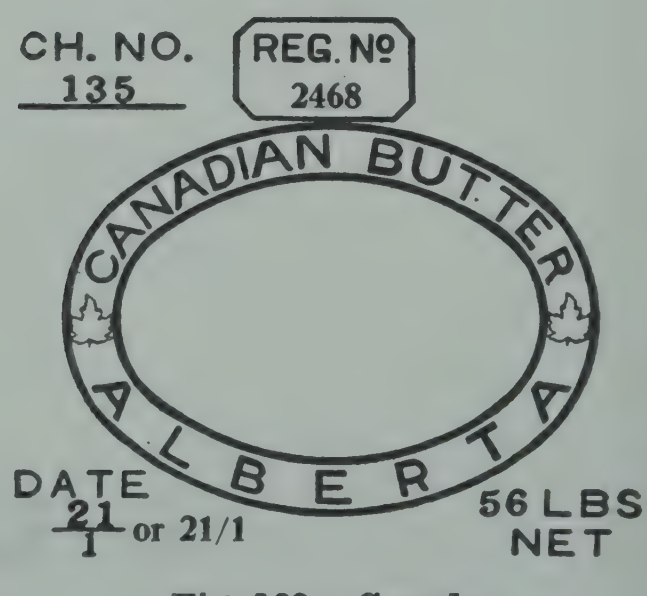


Fig. 109. Canada

ited amount of foreign butter, will serve the interests of the American dairy farmer better than an excessively high tariff that will shut out all foreign butter, but that raises the domestic price of butter to levels that will drive the American consumer away from butter. Once he gets out of the habit of eating butter, the consumer is slow to return to it. It is better, in times of shortage, for some consumers to temporarily eat foreign butter, than to turn to butter substitutes.

REFERENCES

1. ESCHENBRENNER, N. J., Addr. N. Y. Prod. Rev. and Am. Cry. April, (1916).
2. WELD, L. D. H., The Marketing of Farm Products, (1916).
3. SPRAGUE, G. W., and FOELSCH, GERTRUDE G., Unpublished manuscript on Butter Price Quotations at Chicago, Agr. Marketg. Service (1939).
4. The Butter Makers Discussion Club, N. Y. Prod. Rev. and Am. Cry., July 12, (1916).
5. Quoted from Butter Rules, N. Y. Mercantile Exchange, effective May 1, (1935).
6. Quoted from Rules of Chicago Mercantile Exchange, Dec. 1st, (1938).
7. NICHOLLS, W. H., Ia. Agr. Expt. Sta., Res. Bul. 250, (1939).
8. STIEBELING, H. K., and PHIPARD, E. F., U. S. Dept. Agr. B. H. E. Circ. 507, (1939).

CHAPTER XX

THE COLD STORAGE OF BUTTER

Purpose.—The bulk of the butter annually held in cold storage is surplus butter. It is butter produced during the flush season when the supply far exceeds the immediate demand, and when the consumptive channels are unable to provide satisfactory disposition for the vast volume of butter produced. The basic purpose of placing butter in cold storage, therefore, is to take this surplus butter off the market and hold it over from the time of large supply and low prices, to the time of short production and higher prices.

Time of Storage.—The great bulk of butter goes into cold storage in May, June and July and, as shown in Table 46, the storage holdings usually continue to increase until the Month of September (Sept. 1st), which almost invariably represents the time of maximum holdings of butter in cold storage.

May, June and July are the natural storage months of butter in the northern hemisphere, because the freshening of the majority of the cows in the spring time, and the succulent condition of the pastures during these months, provide a natural surplus of butter, and cause butter prices to be at ebb-tide under market conditions that permit of the free and natural functioning of the law of supply and demand.

In years of early drought, with pastures drying up in midsummer and production dropping off sharply soon after the peak has been reached, the storing season is usually cut short. When the season is blessed with abundant rainfall, keeping pastures green until and into fall, and peak production is sustained, the period during which butter goes into cold storage may be considerably extended and the volume of cold storage butter increased.

The amount of surplus butter for which storage must be provided is influenced also by economic factors, such as relationship between price of butter and earning power of the masses of consumers. Large volume of surplus production inevitably depresses the market price. This in turn stimulates consumption and reduces the surplus that must be stored, pro-

vided that butter prices are allowed to attain their natural level by the free functioning of the law of supply and demand. If at such times, however, the functioning of this fundamental economic law is throttled by the artificial "pegging" of the market to price levels out of reach of the pocketbook of the consuming public, as may happen as the result of the perverted notion that such manipulations benefit the farmer, consumption will invariably drop, accumulation of surplus stocks is accelerated, and the storage holdings increase.

Duration of Cold Storage.—Under normal conditions of production, supply, and demand, the great bulk of the butter that is held in cold storage is taken out of storage within six to nine months after the beginning of the storage season. As shown in Table 46, withdrawals begin after September first and average heaviest during November, December and January. Only in exceptional cases is butter carried over into the second year of storage, and when this is done, it is usually accompanied by a heavy sacrifice in quality and in price.

Not all cold storage butter is held in cold storage until late fall and winter. Considerable quantities are "short held," i.e., they are withdrawn after one or more months. Scarcity of fresh butter of good quality, such as may be due to poor quality of hot weather cream (in July and August), may cause withdrawal of some of the May and June butter from storage. In times of early drought and consequent early falling off of the summer make, and a rapid and sustained rise in butter prices, and when the quality of fresh butter made in midsummer is poor due to hot weather cream, butter dealers often find it advantageous to supply their trade with May and June storage butter. Such butter is usually of better quality and may have been purchased at a more favorable price than has to be paid for midsummer butter. In the case of an open summer and fall, with a continued large make and only a very gradual rise in price, if any, the tendency is to hold the butter in storage longer, until such time as the demand necessitates and prices warrant its movement.

Amount of Butter Held in Commercial Cold Storage.—The monthly storage holdings for the years 1918-1939, inclusive, are shown in Table 46. This table also gives the 5-year averages 1934-1938 inclusive) and the 21-year averages (1918-1938 in-

clusive), per month. The figures further show that according to both the 5-year averages and the 21-year averages, the storage holdings increased monthly from May first to September first, maintained their peak from August first to November first, then declined sharply and were lowest between April first and May first.

Between April first and May first, 1938, the U. S. Government commenced buying and storing butter, and some of the states likewise purchased and stored butter for relief purposes. By November first, 1938, the government had accumulated storage stocks amounting to 102,039,000 lbs. of butter for resale, and for relief purposes. Government buying and storing of butter was continued in 1939. The monthly storage holdings given in Table 46 include the butter held by the U. S. Government and by the states. It is largely for this reason that the figures for the second half of 1938 and for 1939 show monthly storage holdings far in excess of the 5-year and the 21-year averages.

The purchases of butter by the United States Government are made through the agency of the Federal Surplus Commodities Corporation. This corporation is buying butter from the Dairy Products Marketing Corporation, and also from Mercantile Exchanges and from other markets. The Dairy Products Marketing Corporation is an independent private corporation, constituted largely of co-operative interests. It secures its funds for operation from the Commodity Credit Corporation on the basis of revolving loans.

Temperature of Cold Storage.—The temperature at which butter is held in commercial cold storage ranges from —10 to —20° F. This temperature range has been universally adopted for the cold storage of butter by commercial cold storage houses in the United States.

Cost of Cold Storage of Butter.—Some of the large creamery corporations are equipped to provide their own facilities for the cold storage of their butter. However, the great bulk of the country's surplus butter that is placed in cold storage, both by the creameries and by the wholesale produce trade, is stored in commercial cold storage houses, located in the large markets.

The cost of carrying butter in cold storage consists of charges for cold storage, insurance while in storage, loan service

Table 46.—Cold Storage Holdings of Creamery Butter in the United States* (000 omitted)

Year	January First	February First	March First	April First	May First	June First	July First	August First	Sept. First	October First	Nov. First	Dec. First
1918	50,726	26,618	18,808	14,629	9,536	12,698	49,140	88,305	99,334	87,883	80,874	65,111
1919	43,910	36,777	24,191	11,909	9,659	29,435	90,158	123,546	131,388	121,816	100,474	73,654
1920	53,737	38,359	22,568	15,555	7,554	12,872	52,526	101,455	115,558	113,385	101,778	79,750
1921	58,682	41,486	27,103	14,732	7,712	21,682	61,991	82,838	92,292	90,116	77,983	65,129
1922	48,412	35,047	22,582	9,113	3,830	13,202	67,410	103,151	112,039	96,680	73,857	47,773
1923	26,819	16,122	8,910	4,824	3,248	10,112	62,768	101,774	102,731	96,117	76,472	51,508
1924	30,299	15,246	9,847	7,482	8,913	22,348	74,184	134,118	156,440	153,494	135,018	100,832
1925	65,694	45,748	28,789	10,875	3,739	13,036	63,687	109,075	128,403	114,172	94,916	74,754
1926	52,785	39,381	26,313	17,392	17,527	30,561	86,897	131,152	138,151	125,342	100,871	64,381
1927	34,347	17,952	7,952	3,044	3,436	25,404	89,996	145,147	163,701	147,396	118,679	83,224
1928	46,289	28,273	14,404	5,716	5,109	15,952	69,750	120,437	136,175	128,071	105,811	70,985
1929	43,783	24,747	11,910	5,532	5,882	28,369	91,962	151,621	168,952	158,541	138,405	111,650
1030	81,935	60,230	46,530	30,556	22,957	50,378	106,522	145,061	143,089	131,489	109,646	88,012
1931	63,401	46,792	30,672	18,010	17,195	35,155	89,172	115,121	104,678	80,152	56,229	42,242
1932	26,643	22,506	15,243	9,094	10,394	29,160	84,269	110,247	107,259	89,490	66,828	37,207
1933	22,043	17,833	11,580	9,255	9,398	35,159	106,378	150,934	175,476	174,713	160,463	138,166
1934	111,249	75,995	36,853	15,351	11,838	27,161	70,148	108,748	120,467	125,047	111,073	81,034
1935	47,175	18,907	8,110	5,341	5,676	33,096	96,392	149,628	156,855	148,822	120,210	71,948
1936	40,117	21,502	8,217	5,346	4,997	21,157	73,816	103,259	112,106	108,835	105,368	88,966
1937	61,234	42,734	20,678	6,700	6,406	22,904	83,119	123,863	134,885	118,697	98,624	66,191
1938[1]	42,954	31,211	20,930	14,310	19,540	55,266	121,467	172,505	201,543	210,351	193,751	158,872
Average last 5 years	60,545	38,069	18,957	9,409	9,691	31,916	88,988	131,600	145,171	142,350	125,805	93,402
Average 21 years	50,106	33,498	20,580	11,036	9,264	25,957	80,559	122,475	133,411	124,790	106,063	79,113
1939[1]	127,805	111,547	92,800	78,806	70,861	85,168	132,370	165,094	173,093	154,571	128,147	89,752

*1939 Year Book U. S. D. A. [1]Courtesy H. W. Hepburn, Ex. Sec., Am. Butter Inst. 1939.

for financing, and interest on the money "tied up" in, or borrowed on the butter. The general rate of cold storage, including warehouse charge and charge for handling, ranges from 20 to 25 cents per 100 lbs. for the first month, and 12½ to 15 cents per month thereafter. Extra cold storage charges may be made for extra handling in connection with butter inspections during the storage period. The insurance rates vary somewhat, but may average approximately 2 cents per $100.00 value per month. The loan service for financing and the interest charges vary very considerably for different years, different localities, and banking arrangements, and according to special terms and private deals between the contracting parties. In general, the total of the cost of insurance, financing and interest constitutes approximately one-third of the total carrying charges, while the cost of cold storage proper amounts to approximately two-thirds.

While butter may be put in cold storage at any time of the year, and held there for widely varying periods of time, the usual storage period is six months. In the case of "futures," for instance, the predominating duration of the contract is six months. Butter hedged in May and June is sold for November delivery. The carrying charges for six months' storage amount to from 1¼ to 1½ cents. Therefore, if November "futures" is quoted at 1¼ to 1½c above the May or June "spot" price, this spread between "spot" and "futures" is considered sufficient to cover the carrying charges.

Weight Losses of Butter in Commercial Cold Storage.—The weight losses in commercial cold storage, of well made butter worked to a dry body as it should be, are negligible. Checks on weights made on butter held in commercial cold storage (temperature —15° F.) for 10½ months, by Hunziker and Cordes[1], showed the weight loss per 63 lb. tub to be only a small fraction of one ounce (about 0.15 ounce).

The important weight losses, if any, occur before the butter reaches cold storage, particularly with reference to time held in and temperature of the creamery cooler, condition (firmness) of butter and time, temperature and nature of handling between churn and cold storage. The ideal procedure is, where the cold storage and the creamery are located in the same town, and satisfactory arrangements can be made to haul each day's make direct to the cold storage. Where the butter must be shipped to a distant cold storage, weight losses may

best be held down to the minimum by maintaining the creamery cooler at as low a temperature as possible and holding the butter in it before shipping, long enough only to thoroughly chill and firm it. The shipping of butter while in soft condition encourages leakage, and rough handling and jolting when in such condition, accelerate it. Thorough chilling and prompt removal to cold storage are important also from the standpoint of retarding flavor deterioration.

Weight losses due to leakage are more pronounced in the case of salted butter than in unsalted butter. The tendency toward excessive leakage is greatest in heavily salted butter, because both, undissolved salt and brine of high concentration, tend in the direction of unstabilizing and rendering less permanent the emulsion of water-in-fat in the butter.

Heavy weight losses may also occur in the case of leaky butter after cold storage. Cold storage butter, when removed from storage and tempered for cutting into prints and rolls, tends to lose more moisture than fresh butter when printed. This is due to the fact that the freezing of butter disturbs its molecular structure. The formation of crystals of water or brine weakens the emulsion, so that when thawing out, the watery portion is less firmly held than it is in fresh butter, and some of it is liberated by the manipulation to which the butter is subjected in the process of printing, resulting in accelerated leakage. This leakage is particularly noticeable in the case of improperly tempered butter when using butter cutters equipped with the Archimedean screw.

KEEPING QUALITY OF BUTTER IN COMMERCIAL COLD STORAGE

It must be expected that during prolonged storage of butter, such as occurs annually with butter held in commercial cold storage, sacrifice in flavor cannot be entirely prevented. The early work of Rogers[2] and of Gray & McKay[3] showed that the rapidity of change in flavor is, in a general way, in an inverse ratio to the temperature of storage, and that butter keeps better at temperatures below zero degrees F. than at higher temperatures. These fundamental findings are fully supported by years of practical experience in the commercial storing of butter and have led to the general adoption of a temperature

range of —10 to —20° F., as standard for butter storage in American commercial cold storage houses.

Cause of Flavor Deterioration of Butter Held in Commercial Cold Storage.—In the brief discussion of the relation of pasteurization of cream to keeping quality of butter (Chapter XI), it was shown that the bacterial count of butter, both salted and unsalted, almost invariably decreases during the cold storage of butter, indicating that keeping quality of butter held at the low temperatures of cold storage (—10 to —20° F.) appears not to be a biological problem.

Our present state of knowledge of the mechanism of butter deterioration during cold storage, while incomplete, reveals strong evidence that these storage flavor defects are the result of progressive chemical changes due to oxidation processes, causing cleavage of one or more of the constituents of butter. However, neither hydrolysis of the fat due to lipase action, yielding free fatty acids of low molecular weight, i.e., butyric, capronic and caprylic acid, that are associated with rancid flavor; nor autoxidation of unsaturated fatty acids, such as oleic and linoleic, that lead to tallowy flavor, are characteristic flavor defects of cold storage butter. While fat splitting reactions and the production of rancid and tallowy flavor are prone to occur in aging butter at ordinary temperatures, they rarely, if ever, occur in butter stored at —15° F. These observations are supported by the work of Dyer[5] who found that "the development of undesirable flavor in butter held in cold storage at a temperature of 0° F. is not dependent upon oxidation of the fat itself," and "that the production of off flavors so commonly found in cold storage butter is attributable to a chemical change expressed through a slow oxidation progressing in some one or more of the non-fatty substances occurring in the buttermilk." Since such butter is usually high in soluble nitrogen compounds, the results suggest that the protein constituents of butter are involved.

The problem of preventing flavor deterioration in cold storage butter has been the subject of extensive study by dairy experiment station staffs, as well as in the laboratories within the industry. It is now definitely known that among the dominating factors that either incite or accelerate the flavor-damaging chemical reactions are: poor quality of cream, presence of metallic salts, high churning acidity, high salt content and air content of butter.

Keeping Quality of Butter After Cold Storage.—The final test of keeping quality of cold storage butter lies in its ability to withstand rapid flavor deterioration, when it is removed from commercial cold storage on its journey to the trade and the consumer. Upon removal from cold storage, butter may be and usually is exposed for a considerable period (probably from one to three weeks) to temperature conditions that tend to hasten deterioration.

In general, butter that has been held for six to nine months in commercial cold storage, develops off-flavors more readily than fresh butter under the same marketing conditions. This is as might be expected. The progressive chemical changes that occur in cold storage, while slow at the low temperature of commercial cold storage, have the effect of lowering the resistance of the butter constituents involved. When the butter is removed from the protecting influence of low temperature, these changes, already begun, are accelerated and flavor deterioration goes on more rapidly.

Here again the quality of the cream and the churning acidity exert a controlling influence. Butter made from fresh, sweet cream of high quality, having suffered practically no chemical changes during cold storage, has a resistance similar to that of fresh butter of the same grade. It usually is capable of holding its score when taken out of cold storage, and it gives every promise to reach the consumer in satisfactory condition. On the other hand, butter that, because of a poor quality of cream, or of high churning acidity, or both, has suffered chemical changes to the extent of showing noticeable flavor deterioration during the cold storage period, has dissipated its resistance and will tend to depreciate rapidly in flavor, when removed from cold storage. Border-line lots that suggest "weakness" at the end of cold storage, are rarely safe to put out among the fresh butter trade. They almost invariably cause serious quality complaints from the trade and the consumer.

Effect of Cold Storage on Diacetyl Content.—The general tendency is for the Diacetyl and Acetoin content of butter to diminish during the cold storage of butter. However, the diacetyl flavor developed in the cream generally stays with the butter fairly permanently throughout the storage period. On the other hand, the diacetyl flavor of fresh butter, resulting from the addi-

tion to and working into the butter of diacetyl compounds, is relatively unstable and disappears almost completely from butter held in cold storage.

Predicting the Keeping Quality of Butter Intended for Cold Storage.—Details of methods and merits of keeping quality tests are given in Chapter XXV on "Factory Tests." By reason of the low temperature, long period, and relatively slow progressive changes that take place in butter held in commercial cold storage, the results of short-duration incubation tests made at room temperature or higher, cannot be expected to be comparable with the probable behavior of the butter in cold storage. In addition, the merits of incubation tests are largely confined to the revelation of the relative resistance of butter to flavor deterioration due to bacterial causes, while deterioration of butter held in cold storage is not a microbiological problem.

As shown in earlier paragraphs, the churning acidity is a controlling factor of the keeping quality of butter in cold storage. There exists a fairly close relation between the churning acidity and the acidity of butter. It follows, therefore, that the acid test of butter should give some indication of the fitness of butter for cold storage.

A titratable acidity of butter of 0.05% is a dependable indication that the churning acidity of the respective cream was sufficiently low to insure satisfactory keeping quality, relative to absence of flavor-damaging chemical reactions that are incited or accelerated by acidity. Unfortunately, the end point in the acidity titration of butter is somewhat evasive and not as easily detected by the unskilled operator as it should be. Because of this difficulty, the results are occasionally open to question.

The pH determination of butter provides an index of the acidity that, if wisely interpreted, may serve as a fairly dependable indication of the probable keeping quality of the butter. In the case of butter made from sour, neutralized cream, a pH range of from 6.6 to 7.3 has been found a reasonably safe limit. In the case of sweet cream and sweet cream ripened to a controlled limit of safe churning acidity, the pH usually ranges from about 5.8 to 6.5. The colorimetric method of determining the pH of butter serum, given in Chapter XXV, provides a very simple test, the performance of which requires no technical skill.

REFERENCES

1. HUNZIKER, O. F., and CORDES, W. A., Blue Valley Res. Labs. (not publ.), (1934).
2. ROGERS, L. A., Addr. 3rd Intern. Cong. Refrig. Washington-Chicago, (1913).
3. GRAY, C. E., and MCKAY, G. L., U. S. Dept. Agr. B. A. I. Bul. 84, (1906).
4. HUNZIKER, O. F., and CORDES, W. A., J. D. Sc. XVIII, *7*, 452, (1935).
5. DYER, D. C., J. Agr. Res. VI, *24*, 927, (1916).

PART V

Composition, Properties and Defects of Butter

CHAPTER XXI

CHEMICAL COMPOSITION OF BUTTER

Structure.—The theories advanced regarding the formation of butter in churning, and the physical structure of the resulting butter, are discussed in Chapter XV on "Churning." The conception of the structure of butter is not as yet fully unanimous. In general, however, there is agreement among the students of the subject that butter is a solid system of water-in-fat emulsion in which the continuous phase is semi-solid, "free" butter fat, and that in this system are dispersed fat globules, moisture droplets and air bubbles, each type being stabilized by an envelope of protein material.

Chemical Composition.—Butter is principally composed of milk fat, moisture, salt and curd. It also contains small amounts of ash, lactose, acids, phospholipids, and air, as well as microorganisms, enzymes and vitamins.

The relative percentage proportion of the principal constituents of butter is largely controlled by the method of manufacture, and this in turn is chiefly regulated to conform with the standard of composition prescribed by regulations in the different countries, states and municipalities, and by the preference for salt content of the respective markets.

The legal standard for the composition of butter in some countries, including also the United States, designates the minimum fat limit, in others it sets the maximum moisture limit and a few countries have a double standard of minimum fat and maximum moisture limit. Competitive pressure has the inevitable effect of limiting the fat content of butter as nearly as possible to the minimum legal fat limit. The figures in Table 47 suggest the percentages of butter fat and of moisture at which the efficient buttermaker will aim, in his efforts to make butter that conforms to the legal standard of composition, without

putting appreciably more fat into the butter than the law requires. The table further shows the influence of the salt content on the relation of fat to moisture. These calculations assume an arbitrary curd content of 1%.

Table 47.—Composition of Butter Made to Comply With Different Butter Standards

Salt Content of Butter %	Butter Standard 80% Fat, Min.		Butter Standard 16% Moisture, Max.		Double Standard 80% Fat and 16% Moist.		Double Standard 82% Fat and 16% Moist.	
	Fat %	Moisture %	Fat %	Moisture %	Fat %	Moisture %	Fat %	Moisture %
3% Salt	80-80.5	15.5-16	80-80.5	15.5-16	80-80.5	15.5-16	82-82.5	13.5-14
2% Salt	80-80.5	16.5-17	81-81.5	15.5-16	81-81.5	15.5-16	82-82.5	14.5-15
1% Salt	80-80.5	17.5-18	82-82.5	15.5-16	82-82.5	15.5-16	82-82.5	15.5-16
Unsalted	80-80.5	18.5-19	83-83.5	15.5-16	83-83.5	15.5-16	83-83.5	15.5-16

In practical manufacture such approximation of the minimum fat limit, or maximum moisture limit, is possible only in the presence of highly efficient moisture control, as explained in Chapter XVI. Under average conditions, considerably wider deviations from the legal limits occur. The more rigid enforcement of regulations on composition of butter, the narrowing down of the margin of profit, and the increasing skill of the buttermaker, have had the effect, however, of materially decreasing the range of deviations from the legal limits of the percentage composition of butter.

Except in isolated instances of willful law violations, the cases of butter with a fat content below the legal Federal minimum of 80% are few. The cases of butter in which the fat content is far above 80% are also decreasing, and the general average fat content of butter made in the United States is probably in the vicinity of 80.5 to 81%. The following analyses of 861 samples of creamery butter, reported by the Iowa Dairy and Food Division, may serve to convey a general idea of the range and average of composition of commercial American butter:

	Average	Range
Fat	80.85%	77% to 84%
Moisture	15.88%	13% to 19%
Curd	0.89%	—
Salt	2.39%	1% to 4%

THE BUTTER FAT

The butter fat constitutes the chief constituent of butter, providing approximately one-fifth of the composition of normal butter. Butter fat is the fat of milk, which is present in milk and cream in the form of minute fat globules held in suspension in the skim milk portion of the milk.

Fat Globules.—The results of extensive study of the structure of the fat globules by numerous investigators suggest, that each fat globule is coated with a so-called protective film. The inner portion of this film, i.e., the part that lies closest to the fat surface, consists of a more or less continuous layer of phospholipid-protein material. To the water side of this layer is further adsorbed a concentration of skim milk constituents, principally casein. The outer adsorbed material (skim milk constituents) appears to be more loosely held than the inner covering (phospholipid-protein). It is believed that it is the presence of exposed portions of the fat surface, resulting from lack of continuity, or rupture, of the phospholipid-protein film, that assists in the sticking together of the fat globules and the formation of butter granules, when contacting each other during the churning operation.

The fat globules are electro-negatively charged, causing them to repel each other. The electrical potential decreases with increased acidity of the cream. This, together with the increased dehydration of the casein, also due to acidity, expedites the coalescence of the fat globules and the formation of butter granules, shortening the churning time of sour cream.

The fat globules vary widely in size, ranging from a diameter of less than one micron to over 20 microns. The size of the fat globules is influenced principally by breed and individuality of cow, and by the stage of the period of lactation. It is affected also by the condition of the cow and changes in feed. Sudden excitement, and abrupt changes in feed usually cause a temporary increase in size. Table 48 shows that the fat globules in the milk of Jerseys and Guernseys are larger than those in milk from Holsteins, Ayrshires, Holderness and Devons. The table also shows that the fat globules decrease in size as the period of lactation advances.

When the milk is separated (centrifugal separation), the majority of the fat globules that pass into the skim milk are

Table 48.—Effect of Breed and Period of Lactation on the Relative Size of the Globules[1]

Month of Period of Lactation	Breeds of Dairy Cows					
	Jersey 25 Cows	Guernsey 20 Cows	Holstein 9 Cows	Ayrshire 33 Cows	Holder-ness 20 Cows	Devon 16 Cows
1st month	1104	928	....	687	....	546
2nd month	1098	1063	640	580	661	585
3rd month	1228	954	576	624	607	450
4th month	1097	659	256	426	501	547
5th month	1149	839	396	384	397	319
6th month	846	737	595	399	324	355
7th month	1017	584	340	322	329	270
8th month	733	568	310	298	379	200
9th month	715	408	384	241	315	250
10th month	571	426	284	248	336	228
Avg. for year	955.8	716.6	420.1	420.9	427.6	375

of such small size (2 microns and less) that they fail to respond to the separating power of the centrifugal force. In the churning process, the majority of the smallest fat globules contained in the cream pass into the buttermilk.

The size of the fat globules influences the churnability of the cream and the texture of the butter. Large-globule cream churns more rapidly than small-globule cream. Large-gobule cream tends in the direction of a tough, plastic texture with good grain. Small-globule cream yields butter with a short grain, firm body and a tendency to brittleness and crumbliness.

Chemical Composition of Butter Fat.—Butter fat is a natural compound, or mixture, of numerous fatty glycerides. The glycerides consist of one or more fatty acids, combined with glycerol (glycerin) as the base. The chief, definitely known fatty acids of butter fat are: oleic, palmitic, myristic, stearic, lauric, butyric, caproic, caprylic and capric acids. Linoleic and arachidic acids, as well as traces of other fatty acids have also been found in butter fat.

Glycerol, the base of the glycerides, is a tri-hydroxy alcohol. One molecule of glycerol combines with three molecules of fatty acid. If three molecules of the same fatty acid combine with one molecule of glycerol, a simple tri-glyceride is formed. If the three molecules of fatty acid, that combine with one molecule of glycerol, are composed of more than one type of fatty acid, then we have mixed gycerides.

Chemical Structure of Glycerides.—The chemical structure of the glycerides of butter fat is not as yet definitely known. It was formerly believed that butter fat was largely a mixture of simple tri-glycerides, such as olein, palmitin, myristin, stearin, laurin, butyrin, caproin, caprylin, caprin, etc. The early work of Richmond,[2] however, indicated the probability that butter fat exists as mixed glycerides, rather than as simple glycerides. The results of more recent investigations support Richmond's conclusions, and suggest further that none of the above simple glycerides are present in appreciable amount, while there is definitely established evidence that mixed glycerides of fat do exist, as shown by Amberger,[3, 4] Richmond[5] and Hilditch and Jones.[6]

Fatty Acids.—Because of the fact, pointed out by Rogers,[7] that efforts to separate and isolate the individual glycerides of butter fat in pure form, have generally failed, studies of the composition of butter fat have had to do predominatingly with determinations of the percentage of the fatty acids yielded by such analysis. These investigations have revealed the presence of at least 11 different fatty acids.

The percentage proportion in which the different fatty acids are present in the butter fat has been found to vary considerably with such factors as breed, individuality, period of lactation, and feed of the cow. It is, therefore, not surprising that the results of analyses of milk fat for fatty acids, derived from different sources, are often at variance. The problem of comparable analytical results is further complicated by the difficulty, recognized by the foremost authorities, of isolating the fatty acids or their glycerides analytically. Table 49 shows the extreme ranges of individual fatty acids in milk fat, as found by various investigators, and assembled by Stout.[8]

Saturated and Unsaturated Fatty Acids.—Butter fat contains both saturated and unsaturated fatty acids. The designation "saturated" here refers to compounds that are unable to unite directly with other compounds or elements. All of the definitely known fatty acids of butter fat, except oleic acid and linoleic acid, belong to the group of saturated fatty acids.

The designation "unsaturated" refers to compounds which can absorb or unite directly with elements or other compounds. All unsaturated fatty acids have the property of taking up iodine.

Table 49.—Percentage Range of Fatty Acids of Milk Fat and Their Melting Points (Stout)[8]

Fatty Acids	Molecular Weight	Range of Percentage	Melting Point ° C.	Melting Point ° F.
Saturated				
Butyric	88	2.2 to 5.5	— 8	17.6
Caproic	116	1.3 to 3.3	— 9.5	14.9
Caprylic	144	0.5 to 1.9	16.5	61.1
Capric	172	0.3 to 3.0	31	87.8
Lauric	200	2.6 to 7.7	48	118.4
Myristic	228	9.9 to 22.6	58	136.4
Palmitic	256	5.8 to 38.6	64	147.2
Stearic	284	1.8 to 20.4	69	158.2
Arachidic	342	0.0 to 1.2	77	170.6
Unsaturated				
Oleic	282	25.3 to 48.3	14	57.2
Linoleic	280	0.0 to 5.4	—18	— 0.6

In butter fat, oleic acid and linoleic acid are the only definitely known unsaturated fatty acids. Linoleic acid is even more highly unsaturated than olein. Small amounts of this acid (linoleic) have been reported present in butter fat by some investigators. Unsaturated fatty acids are liquid at ordinary temperatures. The extent to which the unsaturated fatty acids are present in butter fat is indicated by the "iodine number."

Soluble and Insoluble Fatty Acids.—Some of the fatty acids of butter fat are soluble while others are insoluble, in water. To the soluble acids belong butyric, caproic, caprylic and capric acids. All the other saturated acids and all the unsaturated acids are insoluble in water, as shown in Table 50. The water-insoluble fatty acids are determined by the "Hehner number." The insoluble volatile fatty acids are determined by the "Polenske number."

Volatile and Non-Volatile Fatty Acids.—Some of the saturated fatty acids, when set free by hydrolysis of their respective glycerides, either by bacterial or enzymotic action, or otherwise, are spoken of as being volatile. They volatize upon steam distillation and are, therefore, commonly known as volatile fatty acids. To this group belong the butyric, caproic, caprylic and capric acids. Lauric acid is also appreciably volatile. Myristic acid has also been reported very slightly and linoleic acid slightly volatile. The non-volatile acids are the myristic,

Table 50.—Proportion of Soluble and Insoluble Fatty Acids in Butter Fat*

Fatty Acids	Chemical Formula	Average Percentage	Range of Percentage	Volatility (Steam)
Soluble Acids:				
Butyric......	C_3H_7COOH	2.932	2.241 to 4.230	Volatile
Caproic......	$C_5H_{11}COOH$	1.898	1.290 to 2.400	Volatile
Caprylic.....	$C_7H_{15}COOH$	.786	.527 to 1.041	Volatile
Capric.......	$C_9H_{19}COOH$	1.570	1.187 to 2.008	Volatile
Total Soluble...		7.186		
Insoluble Acids:				
Lauric.......	$C_{11}H_{23}COOH$	5.849	4.533 to 7.687	Appreciably Volatile
Myristic.....	$C_{13}H_{27}COOH$	19.784	15.554 to 22.618	Very Slightly Volatile
Palmitic.....	$C_{15}H_{31}COOH$	15.167	5.782 to 22.863	Non-volatile
Stearic.......	$C_{17}H_{35}COOH$	14.907	7.803 to 20.370	Non-volatile
Arachidic....	$C_{19}H_{39}COOH$	.612	.500 to 1.000	Non-volatile
Oleic........	$C_{17}H_{33}COOH$	31.895	25.273 to 40.313	Non-volatile
Linoleic......	$C_{17}H_{31}COOH$	4.135	1.900 to 5.900	Slightly Volatile
Total Insoluble.		92.349		
Total Fatty Acids........		99.535		

palmitic, oleic, stearic acid and minor quantities of a few others. The volatile fatty acids are predominatingly water-soluble and, therefore, belong to the group of soluble fatty acids. The volatile fatty acids are determined by the "Reichert-Meissl value."

In Table 50 it is attempted to show the percentage proportion in which the individual fatty acids and their several groups are present. It should be recognized, however, that the differential indices as to soluble or insoluble, and volatile or non-volatile acids, are not so sharply defined. Both the solubility and the volatility diminish with increasing molecular weight.

This fact, together with the variableness of the percentage of the individual fatty acids in each group, renders the accurate estimate of the percentage proportion of each group of fatty acids in the butter fat uncertain. Available analyses from a multitude of sources, however, suggest that the volatile fatty

*Percentage figures derived from tables by Holland et al,[9] representing 21 samples of butter fat from Massachusetts cows fed normal rations, except figures for "Arachidic" and Linoleic acids, which are averages of 11 and 14 analyses, respectively, assembled from tables by Lea,[10] Holm and Greenbank,[11] and Eckels, Combs and Macy.[12] Designations relative to volatility were taken from Holm and Greenbanks.[11]

acids make up approximately 12 to 17 per cent of the total butter fat.

The volatile fatty acids are possessed of a strong odor. The most important, and also the most variable member of this group is the butyric acid. It is so named because of the fact that it is produced by hydrolysis of butter fat "butyrum." The butyric acid is believed to contribute largely to the characteristic flavor of butter. It has an intense, rasping, rancid odor, and when liberated by hydrolysis, is responsible for the rancid flavor of butter and other dairy products. The butyric acid is determined by the "Kirchner number."

Investigations[13] have shown that the volatile acid content of butter fat from Jerseys is higher than that from Ayrshires and Holsteins; and that it is highest at the beginning of the period of lactation and lowest in advanced lactation. Feeds rich in starches and sugars, such as corn silage, roots, etc., tend to increase the percentage of volatile fatty acids, while feeds rich in vegetable oils, such as linseed meal, glutenfeeds rich in fat, also dry hay, tend to decrease the percentage of volatile fatty acids contained in the butter fat. It was further shown by Smith and Dastur[50] that inanition caused a decrease of about 80% in the original content of lower acids up to and including C_{14}, which includes all the volatile acids as well as lauric and myristic acids, and that this decrease was almost completely compensated for by a corresponding increase in the content of olein.

The non-volatile fatty acids and their glycerides are insoluble, odorless and tasteless. Those that are saturated, such as the stearic, palmitic, myristic and lauric acids, are solid, while the unsaturated fatty acids to which belong the oleic and linoleic acids, are liquid at ordinary temperatures.

The glycerides of the non-volatile fatty acids, both saturated and unsaturated, are estimated to make up approximately 83 to 88 per cent of the butter fat. Because of the dominating proportion of the non-volatile fatty acids, and of the fact that this group contains both saturated (solid) fats and unsaturated (liquid) fats, this group of fatty acids has a marked influence on the body of butter. Of this group the oleic acid and the palmitic acid are present in larger amounts than any other single non-volatile fat. In average butter fat the oleic acid makes up approximately one-third of all the fatty acids in the butter

fat. Its percentage is also the most variable of any of the non-volatile fatty acids.

Because of its dominating proportion, and the fact that it is liquid at ordinary temperature, the factors that influence its percentage, control to a considerable extent the consistency of the butter fat and butter. The firmer butter produced by Jersey cream over Holstein and Ayrshire cream is attributable, in part at least, to the fact that the olein content of Jersey cream is lower than that of the cream from Holsteins and Ayrshires. The olein content of butter fat is lowest during early lactation and tends to increase somewhat with advancing lactation. Green pasture and also feeds rich in vegetable oils, such as linseed meal and glutenfeeds containing 3% or more of fat, cause a marked increase in the percentage of olein, while dry hay, and feeds rich in starches and sugars, tend to decrease it. It is largely because of this effect of the feed on the olein content of the butter fat and butter, that summer butter tends to be soft and requires low temperature cream cooling, and that winter butter tends to be hard and crumbly, and makes deep cooling of cream undesirable, unless accompanied by other modifications in the process of manufacture.

Properties of Butter Fat.—With reference to their effect on the body of butter, the properties of butter fat have to do chiefly with its melting point. Other properties of the butter fat that are of outstanding importance as related to butter are its color, ability to absorb extraneous odors, vitamin properties, and susceptibility to hydrolysis and oxidation leading to damaging flavor deterioration.

Melting Point of Butter Fat.—Fleischmann shows the melting of butter to range from 31 to 36° C. (87.8 to 96.8° F.), and the solidifying point from 19° to 24° C. (66.2 to 75.2° F.). These ranges are in close agreement with reports from other investigators. The melting points of the different fatty acids are shown in Table 49.

The melting point of the fatty acids might be expected to show some correlation to the melting point of their respective glycerides. As far as the general direction is concerned, this appears to be the case, as indicated in Tables 49 and 51. Table 51, however, shows the melting point of butyrin and of olein to

be much lower than that of the butyric and oleic acids, respectively, listed in Table 49.

Table 51.—Melting Point of Fats

Tri-Butyrin	—60 to —70° C.	(—76 to —94° F.)
Olein	5° C.	(41° F.)
Myristin	54° C.	(129.2° F.)
Palmitin	61° C.	(141.8° F.)
Stearin	65.5° C.	(150° F.)

Tables 49 and 51 show that it is principally the butyrin and the olein portions of the butter fat that are liquid at ordinary temperatures, and that constitute the soft fats, while the myristin, palmitin and stearin are solid at ordinary temperature, and are the principal hard fats. The proportion in which these two groups are present in butter, determines to a large extent its consistency.

Color of Butter Fat.—The yellow color of butter fat is principally due to the presence of carotene and xanthophyll. These substances belong to a group of pigments called carotinoids, which are soluble in fats and in fat solvents, insoluble in water, and more or less subject to oxidation and bleaching. They are derived from the green leaves of plants and from roots, such as carrots. In milk they are associated with the milk fat to which they are directly transferred from the feed through the blood stream. The yellow color is largely confined to the liquid fats of the unsaturated fatty acids, such as olein and linolein.

Since green feeds are richest in carotinoids, the butter fat produced in spring and early summer is more deeply yellow than winter butter fat. The cow appears to be the only mammal supplying milk for the human family, whose milk fat contains these fat-soluble pigments in appreciable amounts. The carotene content of milk fat varies also with breed and individuality of cow. When on green feed, the Jerseys and Guernseys produce a much more highly colored butter fat than the Holsteins and Ayrshires. Because of this influence of feed and breed, the yellow color of butter fat will vary with season and locality.

The carotinoids are associated with the fat-soluble vitamins of milk and butter, particularly vitamin A. See "Vitamins" later.

Absorption of Odors by Butter Fat.—Butter fat has the property of readily absorbing odors from the atmosphere, or from other products that liberate volatile substances. The presence of foreign odors and flavors in butter depreciates its market value. It is, therefore, important to protect cream and butter against contact with objectionable odors from any source. This applies to the production and handling of the cream on the farm and in transit, and to the transportation and the storage of butter in warehouses, retail stores and the family refrigerator.

Decomposition of Butter Fat.—Prevention of the spoilage of butter fat is an important factor in the control of the keeping quality of butter. Decomposition of butter fat may be brought about by hydrolysis, or by oxidation, or both.

Hydrolysis.—Hydrolysis causes the splitting of the fatty glycerides into free fatty acids and glycerol (glycerin). This is brought about by certain species of bacteria, yeasts and molds, and by enzymes (lipases). Fat hydrolysis is the cause of rancid flavor in butter. It is retarded, if not entirely prevented, by efficient pasteurization of the cream, that destroys fat-splitting micro-organisms and enzymes, and by low storage temperature of the butter. See also "Rancid Butter," Chapter XXIII.

It is generally agreed among food chemists that the designation rancidity in butter refers to the off-flavor that is produced by fat hydrolysis. It is the flavor and odor that is characteristic of the free volatile fatty acids of butter fat, particularly butyric acid, which has a pungent, rasping odor that closely resembles the odor and flavor of rancid butter. Rancidity should not be confused with talloviness. While both flavor defects result from fat decomposition, rancidity proper is strictly the result of fat hydrolysis, while tallowiness is due to oxidation of the fat. These two terms are frequently confused, or considered synonymous, or the term rancidity is occasionally loosely used to describe any off-flavor of fat or butter. Such confusion is unfortunate, as it may lead to misinterpretation of experimental data, beclouding the causes of these flavor defects, and increasing the difficulties of effective prevention.

Oxidation.—The exact reactions involved in the spoilage of butter fat by oxidation are not fully understood. Fats are capable to absorb oxygen, causing autoxidation. In butter fat it is particularly the unsaturated fats, such as olein and linolein, that

are attacked. In butter, autoxidation is facilitated by the fact that the oxygen can diffuse through the mass through the medium of the aqueous films and interface properties of a multiphase system.

The rate of oxygen absorption by the butter fat is slow at first and a considerable time elapses before there has been sufficient oxidation to show appreciable flavor deterioration. This initial period is called the "induction period." After this period, oxygen absorption will progress at an increasingly rapid rate. It is believed that the retardation of oxygen absorption during the induction period is due to the presence in the fat of traces of non-fatty compounds that have the properties of "anti-oxygens." These guard the fats proper from oxidation. They gradually lose this property, however, becoming themselves oxidized to non-anti-oxygenic forms, after which autoxidation of the fat sets in and flavor deterioration becomes definitely noticeable. In butter fat and butter, fat oxidation produces tallowy flavor (see Tallow Flavor, Chapter XXIII).

Fat oxidation is hastened in the presence of air, light, high temperature (room temperature), acidity, alkalinity and the presence of metals, such as copper and iron, their oxides and salts. The free fatty acids are even more susceptible to oxidation than the glycerides themselves. Free glycerol also yields to oxidation. Slight hydrolysis of the fat, therefore, may incite and hasten fat oxidation.

COMPOUNDS ASSOCIATED WITH BUTTER FAT

Cholesterol.—Natural fats contain varying, but usually small quantities of sterols, such as cholesterol, as well as ergosterol. Cholesterol is a very complex mono-hydric alcohol. It is insoluble in water, and its melting point is approximately 146° C. (294.8° F.). The cholesterol content of butter fat is variously quoted at from 0.071% to 0.43%. Grimmer and Schwartz[14] found separator slime of approximately 27% solids content to contain 0.1568% cholesterol. Sommer[15] points out that in this group (sterols), of which cholesterol is a member, "we have the precursor of vitamin D. Ultra-violet radiations activate this precursor, and this makes it possible to increase the vitamin D potency of dairy products by irradication."

Lecithin, $C_{42}H_{84}NPO_9$, and Cephalin.—These products belong to the group of phospholipids. They are colorless, viscous,

nitrogenous-fatty substances containing phosphorus; they are hygroscopic and chemically active. The phospholipids are found abundantly in brain and nerve tissues.

Holm, Wright and Deysher[16] reported the following lecithin content in dairy products:

Whole Milk	0.158% Lecithin
Skim Milk	0.129% Lecithin
Cream	0.269% Lecithin
Butter	0.247% Lecithin
Buttermilk	0.318% Lecithin

Horrall[17] found the lecithin content of normal milk to be quite uniformly 0.6% of the weight of the fat in the milk. Thus, for milk containing 3.9% fat, the lecithin content of the milk would be 0.0234%. He found the lecithin content of colostrum milk fat highest, decreasing as the lactation advanced. Horrall likewise reported that udder infection increased the per cent lecithin of the milk fat. He further found the lecithin content of skim milk to average 13.91% of the fat. Pasteurized sweet cream butter averaged 0.232% lecithin in the fat, while pasteurized neutralized sour cream butter contained 0.17% lecithin. Buttermilk from pasteurized sweet cream averaged 19.66% lecithin in the fat, while buttermilk from pasteurized, neutralized sour cream averaged 17.88%. The per cent lecithin in the fat of separator slime averaged 12.38%. The lecithin content decreased materially in salted butter from sour cream, while that of sweet cream butter remained practically the same over a storage period of 24 days.

Upon hydrolysis, lecithin yields choline as one of its decomposition products, and the oxidation of choline liberates the fishy trimethylamine. The reactions are hastened in the presence of acid and salt, and they are further intensified by metals such as copper and iron, through catalysis, and by exposure to air. See also Fishy Butter, Chapter XXIII.

Other Fatty Compounds.—Other compounds associated with butter fat are carotinoids and vitamins which are discussed under "Color of Butter Fat" and "Vitamins," respectively.

FAT CONSTANTS AND THEIR APPLICATIONS

Fats have certain physical and chemical characteristics, arbitrarily known as constants. Determination of these constants

assists in revealing information of the true nature of the fat, of the probable proportion in which different groups of fatty acids are present, of the possible presence of adulterants, and to a certain extent, of fat deterioration due to hydrolysis or oxidation.

Melting Point.—The melting point of butter fat has a direct bearing on the relative firmness of the butter fat and butter. In general, the higher the melting point of butter fat the firmer the butter, and the lower the melting point, the softer the butter. This is usually true in cases of extremes of high and low melting points. The relation of melting point to firmness, however, is not always definite and constant. Different samples of butter, all having the same melting point, may and frequently do vary very appreciably in their relative firmness. Occasionally soft butter is associated with a relatively high melting point, and hard butter with a relatively low melting point.

Usually, the conditions that cause a rise in the iodine number (unsaturated fatty acids), and in the Reichert-Meissl value (volatile fatty acids), lower the melting point and vice versa. Here again, this trend is not without recorded exceptions in which the opposite relationship prevailed.

Butter fat, being a mixture of glycerides of different fatty acids, does not have a very sharply defined, definite melting point. The constant called melting point is, therefore, of somewhat arbitrary character. The average melting point of pure butter fat is generally near 34° C. (93.2° F.). Its usual variations are small, ranging from about 32 to 36° C. (89.6 to 96.8° F.). In extreme cases it may vary from about 28 to 40° C. (82.4 to 104° F.). In instances of feed rations high in cottonseed products, it has been found to go as high as 44° C. (111.2° F.). The melting point of oleo oil, lard, beef tallow and mutton tallow is usually higher than that of butter fat, ranging from about 36 to 50° C. (96.8 to 122° F.), while that of cocoanut oil is low, averaging from 20 to 28° C. (68 to 82.4° F.). Adulteration of butter fat with these animal or vegetable fats, therefore, will tend to raise or lower the melting point of the butter fat accordingly.

Refractive Index.—This constant refers to "optical refraction," i. e., it signifies the ratio of the angle of incidence (of the light emerging from air) to the angle of refraction (of the same ray of light) in the substance tested. Its determination supple-

ments some of the evidence relative to other constants. Thus, high iodine numbers and high Reichert-Meissl values, are usually accompanied by a relatively high refractive index. Determinations of the refractive index have the advantage of rapidity of test.

At 40° C. (104° F.) the refractive index of pure butter fat may be expected to be approximately 1.4540 to 1.455. Normal ranges generally fall within the limits of 1.4527 to 1.4566. Oleo oil, lard, beef tallow and mutton tallow have higher refractive indices than the maximum for butter fat, ranging from about 1.4570 to 1.4600. The refractive index of cocoanut oil is far below that of butter fat, ranging from about 1.447 to 1.4495.

Reichert-Meissl Value.—This constant indicates the extent to which the volatile fatty acids are present. It is determined by the number of cc. of $\frac{N}{10}$ alkali required to neutralize the volatile fatty acids distilled (under especially prescribed conditions in a standard apparatus) from 5 grams of fat. Normal variations range from about 27 to 30. It seldom drops below 24 or rises above 34, although instances of a Reichert-Meissl value as low as 20 have been recorded. The relatively high Reichert-Meissl value (high volatile acidity) of butter fat distinguishes the milk fat from all other fats. Thus, oleo oil, lard, beef tallow and mutton tallow have a very low Reichert-Meissl value, usually about 0.3 to 0.5. For cocoanut oil this constant is also low, averaging about 6.0 to 8.5.

Polenske Number.—This is the number of cc. of $\frac{N}{10}$ alkali required to neutralize the insoluble volatile fatty acids obtained by the Reichert-Meissl distillation from 5 grams of fat. The Polenske number of pure butter fat ranges from about 1.5 to 3.5. Most volatile fatty acids in milk fat are soluble in water. This constant is lower in oleo oil, lard, beef tallow and mutton tallow, averaging about 0.4 to 0.6. In cocoanut oil, it is much higher than it is in the butter fat, ranging from 15 to 20.

Hehner Number.—This shows the water-insoluble fatty acids in a fat. In milk fat it ranges from about 86.5 to 89.8.

Kirchner Number.—This constant is a measure of the butyric acid in a fat. It shows the number of cc. of $\frac{N}{10}$ alkali required to neutralize the butyric acid (separated from the other

volatile acids by reason of the solubility of its silver salt) distilled from 5 grams of fat by the Reichert-Meissl determination. The Kirchner number of pure milk fat ranges from about 19 to 26.

Saponification Value (Koettstorfer).—This constant shows the number of milligrams of KOH required to saponify one gram of fat. The saponification value of pure butter fat is generally around 228. Normal variations range from about 226 to 230. Extreme variations usually fall within the limits of 220 to 240. For oleo oil, lard, beef tallow and mutton tallow, the saponification value lies within the range of about 192 to 203. For cocoanut oil it is considerably higher than for butter fat, averaging about 250.

Iodine Number (Hanus).—This indicates the percentage of iodine absorbed by a fat. It is a measure of the proportion of unsaturated acids in a fat, such as oleic and linoleic acid. In pure butter fat the iodine number averages about 32. Usual variations are from 30 to 34. Extreme variations are generally within the limits of 26 and 38, though both lower and higher limits have been reported.

The iodine number of oleo oil, lard, beef tallow and mutton tallow generally exceeds that of butter fat, ranging between 40 and 50; in the case of lard as high as 70. The iodine number of cocoanut oil is very low, ranging about from 6 to 10.

Acid Value.—The acid value is indicative of the free fatty acids present in fat. It shows the number of milligrams of KOH required to saturate the free fatty acids in one gram of fat. This test indicates the amount of fatty acids not combined with the glycerol base. The acid value of fresh butter fat ranges from approximately 0.4 to .56. Slight increases in the acid value are usually accompanied by pronounced flavor deterioration associated with rancidity.

THE CURD

Curd by Difference.—For creamery purposes the curd content of butter is determined by difference. It is calculated by deducting the sum of the percentages of moisture, fat and salt from 100. The per cent curd by difference thus is not limited to the protein content alone, but includes all the ingredients of butter, other than fat, moisture and salt. In other words, it

consists of the non-fat buttermilk solids contained in butter, the more important of which are protein (consisting mainly of casein and perhaps traces of albumin, and of phospholipid-protein material), ash, lactose and acid.

Knowledge of the percentage of curd by difference provides the missing link in calculations to determine the total of the percentages of moisture and salt that butter of the desired fat content may contain. It assists the buttermaker in his calculations of the creamery overrun. In creameries with efficiently standardized methods of manufacture, the percentage of curd by difference is fairly uniform. Under normal conditions of operation, it usually averages about 0.7 to 0.8%. It rarely exceeds 1.0% and may drop as low as 0.4%. Bird and Breazeale[18] determined the curd by difference in samples of 50 different lots of butter, in duplicate, by the three most approved methods of analysis. A summary of their results is shown in Table 52.

Table 52.—Percentage of Curd by Difference
(Bird and Breazeale)[18]

	Percentage of Curd by Difference		
	A.O.A.C. Method	Modified Official Method	Kohman Method
Average.....	0.781	0.741	0.777
Maximum...	0.957	0.930	1.120
Minimum...	0.556	0.450	0.440

The averages and ranges of percentage of curd shown in Table 52 are in agreement with the findings of Hunziker[19] relative to curd content of butter made by normal methods of manufacture under a wide range of conditions. Long commercial experience has demonstrated that calculations of the per cent of fat in butter, on the basis of an allowance of 1% for curd, provide an ample margin of safety. Thus, if the minimum fat limit is 80%, working to a total of moisture and salt of 19% is a very safe practice.

The curd content of butter is usually increased to slightly over one per cent (about 1.25%) by working starter into the butter. If milk solids are added to the butter in the form of dried casein or dried skim milk, the curd content may be increased very materially. Experimental results by Hunziker and Hosman[20] show that butter so treated may contain as high as

10% protein curd. In the case of adding skim milk powder the curd by difference may rise to 15%, because a considerable portion of the milk sugar and ash of the skim milk powder are also retained by the butter. In addition, such high protein curd increases the moisture holding property and thereby facilitates the incorporation of high moisture. Such practices would obviously be in violation of the legal standard of butter composition. The sole purpose of their reference here is to point out the factors that influence the curd content of butter.

Constituents of the Curd and Their Properties.—The curd by difference is made up chiefly of the protein curd of the buttermilk, milk ash, milk sugar, citric acid and lactic acid.

Protein Curd.—The nitrogenous curd in butter is usually expressed as protein curd. It is determined by analyzing the butter sample for nitrogen and multiplying the results by 6.38. The protein curd of butter manufactured by normal methods usually ranges from about 0.30 to 0.45 per cent. Wyant[21] found it to average 0.3726% with a minimum of .3155%, and a maximum of 0.4372%.

Efforts to increase the protein content of butter by not washing the butter, or by working the butter in the buttermilk, will raise it somewhat. Wyant's work showed unwashed finished butter to average 0.517% protein, and butter worked in the buttermilk, to average 0.5264% protein. Working starter into the butter yielded a protein content of 0.4718%.

The protein curd constitutes approximately 50% of the curd by difference. It contributes to the coherence and plasticity of the characteristic texture of butter as compared with pure fat. It assists in the moisture-retaining property of butter, and it supplies essential food for the germ life that may be present in butter, thereby making possible deterioration due to bacterial causes. The protein curd of butter consists chiefly of casein. It may embrace also traces of albumin, mucoid protein, phospholipid-protein material, and nuclein.

Casein.—In the fresh milk the casein is present in combination with calcium oxide, forming calcium caseinate. It reacts acid toward phenolphthalein, and behaves toward bases in a manner similar to acids, forming salt-like combinations. It is soluble in weak alkalies and strong acids and is coagulated by strong alkalies, weak acids, the salts of a number of metals, and

by rennet. It coagulates at ordinary temperature when the acidity of milk reaches 0.6 to 0.7%. As the temperature rises, the per cent acid required to coagulate the casein diminishes. When the milk sours, the casein compound (calcium caseinate) splits into calcium lactate and pure casein.

When sour cream is neutralized with lime neutralizers, such as milk of lime (calcium hydroxide emulsified in water), the acidity of the cream is seldom reduced to the point calculated by chemical equation. Observations in practice are that a portion of the lime is being utilized to combine with the casein. These observations are supported by analytical study of the components of butter by Hunziker and Hosman,[22] who showed that the increase in per cent calcium due to neutralization was much greater in the curd portion than in the serum portion of the neutralized cream. These results are summarized in Table 53.

Table 53.—Relative Action of Lime Neutralizer on Serum and Curd in Cream

Components of Cream	Per Cent Calcium in Cream			
	Before Neutralization	After Neutralization to 0.26% Acid	Increase of Calcium	Per Cent Increase of Calcium
Cream serum.	0.049	0.074	0.025	51.0
Curd........	0.105	0.405	0.300	285.7

The casein is colloidally dispersed in milk. Swedberg, Carpenter and Carpenter[23] reported the radius of the molecular sizes of casein to be 4 μ ($\frac{4}{25{,}000{,}000}$ inch) and Nichols et al[24] found the calcium casein particles in milk heated to 40° C. (104° F.) to vary from 100 μ ($\frac{1}{250{,}000}$ inch) to molecular sizes.

The colloidal nature of the casein in butter assists in accentuating its waxy texture, that distinguishes it from the texture of solidified oil which usually is granular and mealy. The colloidal character of the casein is a factor in the moisture-holding property of butter. Pure butter fat lacks this property.

Albumin.—Published data on albumin content of butter are lacking; however, it is very small. Milk contains about 0.60% albumin, and cream about 0.20%. The heat of flash

pasteurization precipitates a large portion of it. Albumin is soluble in water, dilute acids, and dilute solutions of sodium chloride and sodium carbonate. It is believed to be present in milk, uncombined with a base, but highly dispersed and highly hydrated.

Mucoid Protein.—Mucoid protein has been isolated from the fat globules in cream and butter by Storch,[25] by freeing the fat globules with repeated washing, from all milk serum. He found this mucoid protein different from the other milk proteins and reported that it envelopes the fat globules in the form of a thin, viscous film. He attributed to the mucoid protein the characteristic flavor of butter and believed that the presence of the multitude of microscopic water droplets within the butter granules is made possible by the moisture-holding and emulsifying power of this film of mucoid protein around the fat globules.

Other Nitrogenous Compounds.—Lecithin is a nitrogenous compound associated with the milk fat. It was described earlier under "Compounds Associated with Butter Fat."

Nucleoprotein is believed to be associated with the casein. Comparatively little is known concerning this milk protein. It is present in milk in very small traces and it is doubtful that its effect on the properties of butter is of appreciable consequence.

Lactose.—Lactose, $C_{12}H_{22}O_{11}$, is the carbohydrate of milk. It is in complete solution in milk and cream. Its content in butter is confined to a small fraction of one per cent (approximately 0.15 to .25%). It has been found to decrease slightly in butter held in storage, partly due to probable conversion of small portions, through bacterial or chemical action, to lactic acid, glycollic acid and other acids, and partly due to loss of brine by leakage. In normal butter its effect on the properties of butter is negligible, except that its presence provides food for bacteria. Being a powerful reducing agent, lactose when present in considerable amount, promotes oxidation in butter, especially in a weakly alkaline condition.[51] In butter made from over neutralized cream, lactose may accelerate oxidation, resulting in tallowy flavor and bleaching. In butter with a decided acid reaction, however, the lactose tends to exert a slight preservative influence.

Ash.—The ash of butter contains the mineral constituents of milk. It is present in butter to the extent of approximately 012%. Its composition is similar to that in milk. According to Fleischmann[26] the butter ash has the following composition:

Table 54.—Composition of Ash in Butter from Sour Cream[26]
Butter Not Washed But Thoroughly Worked

Potassium oxide	19.329%
Sodium oxide	7.714%
Calcium oxide	23.092%
Magnesium oxide	3.287%
Iron oxide (ferric) and sulphuric acid	.288%
Phosphoric acid (anhydride)	44.273%
Chlorine	2.604%
	100.587%
Less oxygen equivalent to chlorine	.587%
	100.000%

Citric Acid.—Citric acid is a normal constituent of milk and cream. Its formula is $H_3C_6H_5O_7 \cdot H_2O$. The citric acid content of milk appears to vary widely with different cows and with the same cows when fed different feeds. Rice and Markley[27] show these variations to range from .116% to .199% and Markley[28] gives the limits of .11% to .22%. Sherwood and Hammer[29] report the results of 335 citric acid determinations on milk from individual animals of the four principal dairy breeds. Their results show variations ranging from .07% to .33% citric acid averaging .18%. These investigators found that breed, time of day, and season of year have no significant effect on the citric acid content of the milk. Green feeds increase the citric acid content while the development of lactic acid in milk by bacteria diminishes it.

Variations in citric acid in milk do not seem to have any definite relation to the titratable acidity. In fact, the citric acid appears to be present in the milk in the form of citrates, and their effect on the titratable acidity is very slight. Rice and Markley[27] estimate that the citric acid content might account for about 0.01% titratable acidity of milk.

In butter manufacture, the citric acid content of starter milk and of cream is important in that citric acid and citrates are utilized by flavor and aroma organisms to produce the prod-

ucts that are responsible for the typical desired butter flavor and aroma. In addition, the amount of citric acid or citrates present influences the amounts of flavor products produced and the intensity of the desired flavor. See Chapters XIII and XIV on Starters, and Cream Ripening, respectively.

THE MOISTURE

The water content of butter represents the largest non-fat constituent. Its percentage is greater than that of all of the other non-fatty constituents combined. Under average normal conditions of raw material and method of manufacture, the moisture content rarely exceeds 16%. In fact, in the absence of any effort at moisture incorporation, butter worked to a dry body would not average above approximately 14 to 14.5% moisture.

Moisture Droplets in Butter.—The moisture in butter is of two distinct and separate sources, namely, the buttermilk that is churned into the butter granules, and the extraneous water (washwater) that is incorporated during the working process. The buttermilk moisture consists of exceedingly minute droplets, finely dispersed and securely held within the butter granules. These moisture droplets are so small that, although they contain suitable food for bacteria, they are not of sufficient size to provide enough water for bacterial activity and the majority of them are sterile, as shown by Rahn and Boysen.[30]

The extraneous water that is incorporated during the working process is less finely dispersed and provides sufficient moisture for bacterial requirements, but it lacks in food constituents needed for bacterial activity. The size of the moisture

Table 55.—Moisture Droplets in Butter
(Boysen)[31]

Average Diameter Microns	Number Per cc.	Average Diameter Microns	Number Per cc.
1.9	12,905,700	40.0	57
4.0	230,490	50.0	25
7.5	61,469	60.0	12
12.5	10,740	70.0	8
20.0	628	80.0	5
30.0	139	90.0	4

droplets from this source depends on the extent and intensity to which the butter is worked. The size of moisture droplets in butter and their numerical distribution was determined by Boysen.[31] They are shown in Table 55.

THE SALT

The salt is one constituent of butter that is foreign to the natural composition of butter. While the milk ash contains a very small percentage of salt, about 0.03%, this is so small as to be considered negligible. Unsalted butter, therefore, may consistently be said to contain no salt. For details on effect of salt on the properties of butter see Chapter XVI under "Salting Butter."

THE ACIDITY OF BUTTER

Titratable Acidity.—The titratable acidity of butter depends primarily on the churning acidity, or more correctly, the serum acidity of the cream at churning time. It is also affected, though to a lesser extent, by the thoroughness with which butter is washed. See also Chapter XXV under "Determination of Keeping Quality of Butter."

pH.—The pH of butter, while also related to the churning acidity of the cream, is materially influenced by the original

Table 56.—Relation of Churning Acidity of Cream to pH of Butter*

(Hunziker, Cordes and Nissen)[32]

Kind and Treatment of Cream Containing 32.5% Fat	Churning Acidity of Cream %	pH of Butter
Sweet Cream	0.15	6.32
Sweet Cream ripened to .25%	0.25	5.78
Sweet Cream ripened to .5%	0.51	4.85
Sweet Cream ripened to .8%	0.79	4.31
Sour Cream .50% acid neutralized to .15% (lime)	0.151	6.88
Sour Cream .50% acid neutralized to .15% (soda)	0.176	6.58
Sour Cream .50% acid neutralized to .25% (lime)	0.253	6.03
Sour Cream .80% acid neutralized to .25% (lime)	0.238	6.46
Sour Cream .80% acid neutralized to .25% (lime and soda)	0.235	6.50
Sour Cream .80% acid neutralized to .15% (lime and soda)	0.173	7.05

*Averages of 3 churnings of each comparison (30 churnings in all).

acidity of the cream and the treatment it received, whether neutralized and to what extent. Table 56 may serve to convey somewhat of an idea of the relation of the titratable acidity of the cream at churning time to the pH of the resulting butter, made from cream with a range of churning acidities from 0.15 to 0.80%, with and without neutralization to 0.15% and 0.25% acid, respectively.

The relation of titratable acidity and of pH of butter to keeping quality is discussed in detail in Chapters XIV, XX, and XXIII, under "Effect of Cream Ripening on Keeping Quality"; "Keeping Quality of Butter Held in Commercial Cold Storage"; and "Flavor Defects that May Develop after Manufacture," respectively.

ENZYMES

Enzymes are chemical substances produced by living plant and animal cells. The chemical structure of enzymes is as yet unknown. They are known by their action on substances or substrate. They are capable of accelerating chemical changes already in progress, without being themselves altered, or becoming part of the products formed. In this respect they resemble true catalysts. Extremely minute quantities are capable of bringing about profound and far-reaching changes.

Unlike micro-organisms, enzymes do not depend for their functions on food, moisture, and air supply. They do not reproduce themselves, they do not increase nor become invigorated. Their action is independent of living cells, they are colloidal in nature and non-dializable, they do not form a true solution. Their action is influenced by acidity, alkalinity and salt concentration of the medium, by heat, and under certain conditions by bacteria. Bacteria are capable of affecting enzyme activity through their influence on the reaction. Spitzer and Parfitt[33] showed that the activity of protein-splitting enzymes is slower in an acid medium than in a neutral or alkaline medium. Enzymes are inactivated when the temperature rises above that for optimum activity. Destruction of their colloidal condition is accompanied by destruction of the activity of the enzyme as well.

Some enzymes appear to be inherent in the milk. They are present at the time the milk is drawn. Others are the result of bacterial metabolism. They are present because they have been

secreted by certain species of micro-organisms contained in the milk. To the enzymes that have been found in milk belong lipase, protease, peroxidase, catalase, phosphatase and reductase. Other enzymes that have been reported present in milk are amylase, lactase and diastase. The enzymes that have been studied most in connection with their influence on butter are lipase, protease and peroxidase.

Lipase.—The enzymes of this group, the lipolytic enzymes, have the property of hydrolizing fats (butter fat), yielding free fatty acids and glycerin, and causing rancidity in milk, cream and butter. It is now conceded by the majority of investigators that lipase is present in freshly drawn milk. Pfeffer et al[34] reported that the lipolytic factor is carried in the serum of milk; that when milk is separated, greater lipolytic activity is observed in the skim milk than in the cream; and that the slime of the separator bowl possesses approximately three times as much lipolytic activity as the original milk. Palmer[35] showed that milk from cows in advanced lactation contains true lipase. Rice and Markley,[36] Nair,[37] Koestler,[38] Koestler, Roadhouse and Lortscher,[39] Krukovsky and Herrington,[40] and others found lipase in freshly drawn milk. Lipase in milk and milk products is secreted also by certain species of bacteria, yeasts and molds.

Lipolysis appears to be hastened by shaking milk while the fat is in the liquid or semi-liquid state. Krukovsky and Sharp[41] showed that lipolysis was induced by shaking such milk, and will continue after the milk has been cooled to low temperatures. They attribute the effect of shaking to an alteration in the surface characteristics of the fat globules, which creates a condition more favorable to lipolysis.

The temperature at which butter is held has a marked effect on the activity of the lipolytic enzymes which it may contain. At room temperature the enzyme is active and butter readily yields to rancidity. At the usual temperature of the creamery cooler or store refrigerator, action is materially retarded. At the temperature of commercial cold storage, lipolytic action, if any, appears to be negligible. Butter does not become rancid in cold storage. The usual salt concentration in the serum of salted butter (11 to 18% salt) does not inhibit lipolysis, but the higher salt concentrations do retard it somewhat.

Lipase is readily destroyed at the pasteurizing temperature of cream. Rogers[42] showed that the action of lipase was mate-

rially weakened at 45° C. (113° F.) for 10 minutes, and the enzyme was destroyed at 60° C. (140° F.) for 10 minutes. Rogers, Berg and Davis[43] further demonstrated that continuous pasteurization at 70° C. (158° F.) flash, destroyed lipase. Similar results were reported by Kay[44] who states that flash pasteurization readily destroys tributyrinase (a true lipase) and that even a temperature of 127° F. for 30 minutes was sufficient to destroy 92% of the enzyme.

Protease.—To this group of enzymes belongs the milk enzyme galactase, discovered by Babcock and Russell[45]. Protease causes protein hydrolysis. Aside from galactase, which is inherent in milk, protease enzymes are produced by proteolytic organisms, as shown by Spitzer and Parfitt[33]. The distinctive feature of proteolytic milk enzymes is their power to change insoluble protein compounds like milk-casein into water-soluble forms. Protease is especially active at blood heat (98.6° F.). It is somewhat less active at ordinary temperature (70° F.), at the cold storage temperature of butter (—10 to —20° F.) its activity is practically completely inhibited.

Galactase is concentrated in the slime of the cream separator bowl. Rogers et al[43] found that water-soluble nitrogen increased very rapidly in buttermilk. The increase was greatest in buttermilk from raw cream and least in buttermilk pasteurized at 93° C. (200° F.) Between 71 and 77° C. (160 and 170° F.) this increase was much diminished, showing that pasteurization between these temperatures strongly inhibited the activity of the galactase. The proteolytic agent was not completely destroyed, however, even at 200° F. Thatcher and Dahlberg[46] found that sodium chloride inhibits protease to such an extent that this enzyme cannot act in normal salted butter. In general, the available information regarding the relation of proteolytic enzymes and keeping quality of butter suggests, that the usual temperatures of cream pasteurization diminish proteolytic action and to that extent improve the keeping quality of butter, in so far as it depends on freedom from protein decomposition. The salt in butter further retards proteolysis, and in the case of butter held in cold storage (—10 to —20° F.) deterioration due to the factor of proteolytic enzymes appears negligible.

Peroxidase.—Peroxidase belongs to the group of oxidases. It is a natural enzyme of milk, being largely associated with the

cell elements (leucocytes). It is present, therefore, in much greater concentration in the separator slime than in the cream or skim milk. The enzyme liberates active oxygen from peroxides. It has the property of oxidizing readily oxidizable substances by transferring the thus liberated oxygen to them. Gil-

Table 57.—Composition of Mammalian Milks

Kind of Milk	Analyst or Author	No. of Analyses	Specific Gravity	% Water	% Total Solids	% Fat	% Total Protein	% Casein	% Albumin	% Lactose	% Ash
WOMAN—											
Minimum	Koenig[1]	......	1.027	81.09	8.60	1.43	.50	.18	.32	3.88	.12
Maximum	Koenig[1]	......	1.032	91.40	18.91	6.83	4.32	1.96	2.36	8.34	1.90
Average	Koenig[1]	200	......	87.41	12.59	3.87	2.29	1.03	1.26	6.21	.31
	Grimmer[2]	1	1.0348	88.13	11.87	2.24	2.41	1.96	.45	......	.25
	Grimmer[2]	1	1.0285	89.47	10.53	3.02	1.89	.95	.94	4.37	.32
COW—											
Minimum	Farrington & Woll[3]	......	1.0290	82.0	10.00	2.3	2.5	......	......	3.5	.60
Maximum	Farrington & Woll[3]	......	1.0340	90.0	18.00	7.8	4.6	......	......	6.0	.90
Average	Farrington & Woll[3]	......	1.0320	87.4	12.60	3.7	3.2	......	......	5.0	.70
	Van Slyke[4]	5552	......	87.1	12.90	3.9	3.2	2.5	.70	5.1	.70
	Babcock[5]	......	......	87.17	12.83	3.69	3.55	3.02	.53	4.88	.71
GOAT—											
Minimum	Koenig[1]	......	1.0280	82.02	9.84	3.10	3.22	2.44	.78	3.26	.39
Maximum	Koenig[1]	......	1.0360	90.16	17.98	7.55	5.05	3.94	2.01	5.77	1.06
Average	Koenig[1]	200	1.0305	85.71	14.29	4.78	4.29	3.20	1.09	4.66	.76
	Fleischmann[6]	Avg.	1.0320	85.80	14.20	4.50	5.00	3.80	1.20	4.00	.70
	Scheurlen[2]	1	1.0313	87.11	12.89	4.45	3.67	2.00	1.67	4.09	.72
EWE—											
Minimum	Koenig[1]	......	1.0298	74.47	12.98	2.81	4.42	3.59	.83	2.76	.13
Maximum	Koenig[1]	......	1.0385	87.02	25.53	9.80	7.46	5.69	1.77	7.95	1.72
Average	Koenig[1]	32	1.0341	80.82	19.18	6.86	6.52	4.97	1.55	4.91	.89
	Sartori[2]	2500	1.0377	78.70	21.30	8.94	6.34	......	......	5.02	1.00
	Fleischmann[6]	Avg.	1.0369	83.00	17.00	5.30	6.30	4.60	1.70	4.60	.80
BUFFALO—											
Minimum	Szentkiraly[2]	......	1.0310	81.56	15.77	6.69	3.99	......	......	4.16	.72
Maximum	Szentkiraly[2]	......	1.0336	84.23	18.44	9.19	7.78	......	......	5.18	.85
Average	Szentkiraly[2]	......	1.0323	82.69	17.31	7.87	5.88	......	......	4.52	.76
	Fleischmann[6]	2	1.0339	82.93	17.07	7.46	4.59	......	......	4.21	.86
	Rimini[2]	......	......	81.67	18.33	9.02	3.99	3.63	.73	5.06	.86
Mare	Fleischmann[6]	......	1.0310	90.70	9.30	1.20	2.00	......	......	5.70	.40
	Koenig[1]	47	1.0347	90.78	9.22	1.21	1.99	1.24	.75	5.67	.35
	Vieth[2]	......	1.0350	90.13	9.87	.94	1.65	......	......	6.98	.30
Ass	Schlossman[2]	......	1.0330	88.85	11.15	.36	1.31	.98	.33	4.94	.31
	Koenig[1]	5	1.0360	89.64	10.36	1.64	2.22	.67	1.55	5.99	.51
	Ellenberger[2]	......	1.0320	91.23	8.77	1.15	1.50	.94	.53	6.00	.40
Mule	Aubert & Colby[2]	......	......	89.14	10.86	1.98	2.31	......	......	6.04	.53
	Leed[2]	......	......	91.59	8.41	1.59	1.64	......	......	4.80	.38
Sow	Henry & Woll[2]	Avg.	......	80.96	19.04	7.06	6.20	......	......	4.25	1.07
	Koenig[1]	......	......	84.09	15.91	4.55	7.23	......	......	3.13	1.05
Dog	Koenig[1]	......	......	77.00	23.00	9.26	9.72	4.15	5.57	3.11	.91
Cat	Koenig[1]	......	......	81.63	18.37	3.33	9.08	3.12	5.96	4.91	.51

[1]Leach, Food Inspection and Analysis (1920).
[2]Grimmer, Chemie u. Physiologie der Milch (1910).
[3]Farrington and Woll, Testing Milk and Its Products (1916).
[4]Van Slyke, Modern Methods of Testing Milk and Its Prod. (1916).
[5]Wing, Milk and Its Products (1909).
[6]Fleischmann, Lehrbuch der Milchwirtschaft (1915).
[7]Richmond, Dairy Chemistry, (1914).

let[47] reported its optimum temperature to be at 40 to 50° C. (104 to 122° F.). Thatcher and Dahlberg[46] found small amounts of peroxidase in butter.

Spitzer and Taylor[48], found that heating to 62.5° C. (144.5° F.) for 20 minutes had no noticeable effect on the peroxidase in milk, but that flash pasteurization at 85° C. (185° F.) inactivated the greater part of the peroxidase present. Rogers, Berg and Davis[43] reported that peroxidase was destroyed by flash pasteurization at 77 to 79° C. (170.6 to 174.2° F.), but that at 74° C. (165.2° F.) it was always present. Palmer and Miller[49] studied the influence of peroxidase on butter and concluded that "peroxidase in itself is not a factor in the deterioration of storage butter." They held that the enhanced keeping quality observed in butter made from cream pasteurized at high temperatures, is due to the elimination of agents of deterioration other than the enzyme peroxidase.

Summary of Effect of Enzymes on Butter.—Our knowledge of the functions of enzymes in butter is incomplete. Available data suggest that under certain conditions they may play an important role in hastening butter deterioration. In the case of butter made from properly pasteurized cream, their influence on butter deterioration appears to be very limited.

Table 58.—Average Maximum and Minimum Composition of Cow's Milk

Constituents of Milk	Maximum %	Minimum %	Average Composition by Different Investigators: Farrington & Woll[1] %	Van Slyke[2] 5552 Analyses %	Eckles[3] %	Babcock[4] %	Fleischmann[5] %
Water	90.0	82.0	87.4	87.1	87.1	87.17	87.75
Fat	7.8	2.3	3.7	3.9	3.9	3.69	3.40
Casein	4.6	2.5	3.2	2.5	....	3.02	2.80
Albumin				.7	3.4	.53	.70
Milk Sugar	6.0	3.5	5.0	5.1	4.75	4.88	4.60
Ash	.9	.6	.7	.7	.75	.71	.75
Total solids	....	....	12.6	12.9	12.80	12.83	12.25
Solids, not fat	....	....	8.9	9.0	8.90	9.14	8.85

Specific gravity at 60° F. 1.029—1.034; average 1032.
Specific heat at 61°—62.6° F. .9406—.9523 (Chanoz and Vaillant).
At 57°—61° F. .9457, at 81° F. .9351 (Fleischmann[5]).
Freezing point —.54 to —.57° C. Average —.555° C. (31° F.) (Grimmer[6]).
Boiling point 212.3° F. (Hunziker[7]).

See footnotes for table 59.

Table 59.—Average Composition of Cow's Milk, by Major Breeds[3]

Breeds	Fat %	Total Solids %	Solids Not Fat %	Parts of Fat in 100 Parts of Total Solids %
Holstein	3.45	12.29	8.84	28.
Ayrshire	3.85	12.98	9.13	29.6
Guernsey	4.98	14.20	9.22	35.0
Jersey	5.14	14.90	9.76	34.5
Brown Swiss	3.91	13.28	9.37	29.4

[1]Farrington and Woll, Testing Milk & Its Products (1908).
[2]Van Slyke, Mod. Methods of Testing Milk & Its Products (1916).
[3]Eckles, Dairy Cattle and Milk Production (1923).
[4]Wing, Milk and Its Products (1909).
[5]Fleischmann, Lehrbuch der Milchwirtschaft (1915).
[6]Grimmer, Chemie u. Physiologie der Milch (1910).
[7]Hunziker, Condensed Milk and Milk Powder (1935).

Table 60.—Composition of Ash in Normal Cow's Milk[1]

Mineral Constituents in Milk	In Ash %	In Milk %
Potassium oxide (potash)	25.02	.175
Sodium oxide (soda)	10.01	.070
Calcium oxide (lime)	20.01	.140
Magnesium oxide (magnesia)	2.42	.017
Iron oxide (ferric)	.13	.001
Sulphur trioxide	3.84	.027
Phosphoric pentoxide	24.29	.170
Chlorine	14.28	.100
Total ash	100.00	.700

Table 61.—Composition of Colostrum Milk[1]

Time After Calving	Specific Gravity	Water %	Fat %	Casein %	Albumin %	Sugar %	Ash %	Total Solids %
Immediately	1.068	73.07	3.54	2.65	16.56	3.00	1.18	26.93
After 10 hours	1.046	78.77	4.66	4.28	9.32	1.42	1.55	21.23
After 24 hours	1.043	80.63	4.75	4.50	6.25	2.85	1.02	19.37
After 48 hours	1.042	85.81	4.21	3.25	2.31	3.46	.96	14.19
After 72 hours	1.035	86.64	4.08	3.33	1.03	4.10	.82	13.36

Table 62.—Composition of Ash in Colostrum Milk[2]

Potassium oxide	7.23%
Sodium oxide	5.72%
Calcium oxide	34.85%
Magnesium oxide	2.06%
Iron oxide (ferric)	.52%
Phosphoric acid (anhydride)	41.43%
Sulphuric acid	.16%
Chlorine	11.25%
	103.22%
Less oxygen equivalent to chlorine	3.22%
	100.00%

[1]Leach, Food Inspection and Analysis (1914).
[2]Fleischmann, Lehrbuch der Milchwirtschaft (1915).

Table 63.—Composition of Cream

Constituents of Cream	By Centrifugal Separation					By Gravity Creaming
	Snyder[1] %	Richmond[2] %	Fleischmann[3] %	Fleischmann[3] %	Fleischmann[3] %	Koenig[4] %
Water	66.41	39.37	29.6	68.5	72.9	68.82
Fat	25.72	56.09	67.5	25.0	20.0	22.66
Casein } Albumin }	3.70	2.29	1.3	2.8	3.0	3.76
Milk sugar	3.54	1.57	1.5	3.3	3.6	4.23
Ash	.63	.38	.1	.4	.5	.53
Total solids	33.59	60.63	70.4	31.5	27.1	31.18
Solids not fat	7.87	4.24	2.9	6.5	7.11	8.42

Specific gravity—See Chapter XXIV on Definitions and Standards."
Specific heat of cream testing 19.18% fat at 14°-16° C. .9833; at 27.5° C. .8445 (Fleischmann[3]).

Table 64.—Composition of Ash in Cream[3]

Potassium oxide	28.381%
Sodium oxide	8.679%
Calcium oxide	23.411%
Magnesium oxide	3.340%
Iron oxide (ferric)	2.915%
Phosphoric acid (anhydride)	21.735%
Chlorine	14.895%
	103.356%
Less oxygen equivalent to chlorine	3.356%
	100.000%

Table 65.—Composition of Skim Milk

Constituents in Skim Milk	Centrifugal Separation				Gravity Creaming
	Van Slyke[5] %	Snyder[1] %	Richmond[2] %	Fleischmann[3] %	Fleischmann[3] %
Water	90.30	90.25	90.48	90.35	89.85
Fat	.10	.20	.12	.20	.75
Casein	2.75	} 3.60	3.22	} 4.00	} 4.03
Albumin	.80		.42		
Milk sugar	5.25	5.15	4.88	4.70	4.06
Ash	.80	.80	.78	.75	.77
Total solids	9.70	9.75	9.52	9.65	10.15

Specific gravity at 60° F. 1.035 to 1.038; average 1.036.
Specific heat at 14° to 16° C. .9388; at 22.5° C. .9455 (Fleischmann[3]); at 0° C. .940; at 15° C. .943; at 40° C. .952. (Hammer and Johnson[6]).

[1]Snyder, Dairy Chemistry.
[2]Richmond Dairy Chemistry (1914).
[3]Fleischmann, Lehrbuch der Milchwirtschaft (1915).
[4]Leach, Food Inspection & Analysis (1914).
[5]Van Slyke, Modern Methods of Testing Milk and Its Products (1916).
[6]Ia. Agr. Expt. Sta. Res. Bul. 14 (1913).

Table 67.—Composition of Buttermilk

Constituents in Buttermilk	From Ripened Cream: Van Slyke[2] %	Storch[3] %	Snyder[4] %	Vieth[3] %	Fleischmann[1] %	From Sweet Cream: Storch[3] %	Richmond[3] %
Water	90.6	90.93	90.5	90.39	91.30	89.74	90.98
Fat	.1	.31	.2	.50	.50	1.21	.35
Casein	2.8	3.37 (casein and albumin)	3.3	3.60	3.50	3.28	3.51
Albumin	.8						
Milk sugar	4.4	4.58	5.3	4.06	4.00 (milk sugar and lactic acid)	4.98 (milk sugar and lactic acid)	4.42
Lactic Acid	.6	....	....	.75			.01
Ash	.7	.81	.7	.80	.70	.79	.73

Specific gravity of sweet-cream buttermilk 1.0331[3].
Specific gravity of sour-cream buttermilk 1.0314[3].

Table 68.—Composition of Ash in Buttermilk[1]

Potassium oxide	24.53%
Sodium oxide	11.54%
Calcium oxide	19.73%
Magnesium oxide	3.56%
Iron oxide (ferric) and sulphuric acid	.47%
Phosphoric acid (anhydride)	29.89%
Chlorine	13.27%
	102.99%
Less oxygen equivalent to chlorine	2.99%
	100.00%

[1]Fleischmann, Lehrbuch der Milchwirtschaft (1915).
[2]Van Slyke, Modern Methods of Testing Milk and Its Products (1916).
[3]Richmond's Dairy Chemistry (1914).
[4]Snyder, Dairy Chemistry.

Table 69.—Composition of Whey

Constituents of Whey	Van Slyke[1] %	Fleischmann[2] %	Koenig[3] %	Smetham %	Veith[4] from Skim Milk %
Water	93.40	93.15	93.38	93.33	93.00
Fat	.35	.35	.32	.24	.09
Casein	.10	1.00 (casein and albumin)	.86	.88	.92
Albumin	.75				
Milk sugar	4.80	4.90	4.79	5.06	5.45
Ash	.60	.60	.65	.49	.52
Total solids	6.60	6.85	6.62	6.67	7.00

Specific gravity 1.025 to 1.028 (Fleischmann[2]).
Specific heat, at 0° C., .978; at 15° C., 976; at 60° C., .972 (Hammer and Johnson[5]).
[1]Van Slyke, Modern Methods of Testing Milk & Its Products (1916).
[2]Fleischmann, Lehrbuch der Milchwirtschaft (1915).
[3]Leach, Food Inspection & Analysis (1920).
[4]Richmond, Dairy Chemistry (1914).
[5]Ia. Agr. Expt. Sta. Res. Bul. 14 (1913).

Table 70.—Composition of Separator Slime

	Richmond[4] %	Fleischmann[2] %
Water	66.24	68.20
Fat	.50	1.44
Protein	22.	25.34
Milk sugar	.50	1.80 (Milk sugar and other organic matter)
Other organic matter	7.75	
Ash	3.01	3.22
Total milk solids	26.01	30.00

See footnotes for Table 69.

Table 71.—Composition of Ash in Separator Slime[2]

Potassium oxide	3.155%
Sodium oxide	1.325%
Calcium oxide	45.025%
Magnesium oxide	3.361%
Iron oxide (ferric)	1.846%
Phosphoric acid (anhydride)	43.976%
Chlorine	1.691%
	100.381%
Less oxygen equivalent to chlorine	.381%
	100.000%

See footnotes for Table 69.

REFERENCES

1. N. Y. (Geneva) Agr. Expt. Sta. Ann. Rept., (1892).
2. RICHMOND, H. D., Dairy Chemistry, (1899).
3. AMBERGER, C., Chem. Abstr. *7*, (1913).
4. AMBERGER, C., Chem. Abstr. *13*, 3251, (1919).
5. RICHMOND, H. D., Dairy Chemistry, (1920).
6. HILDITCH, T. P., and JONES, E. E., Analyst *54*, 75, (1929).
7. ROGERS, L. A., Fundamentals of Dairy Science, 2nd ed., (1935).
8. STOUT, R. E., Oregon State College, Thesis M. S., (1939).
9. HOLLAND, E. B., GARVEY, M. E., PIERCE, H. B., MESSER, A. C., ARCHIBALD, J. G., and DUNBAR, C. O., J. Agr. Res. *24*, 365, (1923).
10. LEA, C. H., Rancidity of Edible Fats, (1939).
11. HOLM, G. E., and GREENBANK, G. R., Fundamentals of Dairy Science 80, (1935).
12. ECKLES, C. H., COMBS, W. B., and MACY, H., Milk and Milk Products 22, (1936).
13. HUNZIKER, O. F., MILLS, H. C., and SPITZER, GEO., Purdue Agr. Expt. Sta. Bul. 159, (1912).
14. GRIMMER, W., and SCHWARTZ, G., Milchw. Forsch. *2*, 163, (1925).
15. SOMMER, H. H., Market Milk and Related Products 11, (1938).
16. HOLM, G. E., WRIGHT, P. A., and DEYSHER, E. F., J. D. Sc. XVI, 445, (1933).
17. HORRALL, B. E., Purdue Agr. Expt. Sta. Bul. 401, (1935).
18. BIRD, E. W., and BREAZEALE, D. F., Ia. Agr. Expt. Sta. Res. Bul. 144, (1931).
19. HUNZIKER, O. F., Blue Valley Res. Labs. (not publ.), (1920).

20. HUNZIKER, O. F., and HOSMAN, D. FAY, Blue Valley Res. Labs. (not publ.), (1918).
21. WYANT, R. W., J. D. Sc. III, *6*, 452, (1920).
22. HUNZIKER, O. F., and HOSMAN, D. FAY, cited in The Butter Industry, (1920).
23. SVEDBERG, T., CARPENTER, L. M., and CARPENTER, D. C., J. Am. Chem. Soc. *52*, 241, 701, (1930).
24. NICHOLS, J. B., BAILEY, E. D., HOLM, G. E., GREENBANK, G. R., and DEYSHER, E. F., J. Phys. Chem. XXXV, 1303, (1931).
25. STORCH, V., Milch. Ztg., (1897).
26. FLEISCHMANN, W., Lehrbuch der Milchwirtschaft, (1915).
27. RICE, F. E., and MARKLEY, A. L., J. D. Sc. VII, *5*, 468, (1924).
28. MARKLEY, A. L., Information by Correspondence, (1927)
29. SHERWOOD, F. F., and HAMMER, B. W., Ia. Agr. Expt. Sta. Res. Bul. 90, (1926).
30. RAHN, O., and BOYSEN, H., J. D. Sc. XI, *6*, 446, (1928).
31. BOYSEN, H., Inaug. Diss. Kiel, (1926).
32. HUNZIKER, O. F., CORDES, W. A., and NISSEN, B. H., J. D. Sc. XVIII, *7*, 452, (1935).
33. SPITZER, GEO., and PARFITT, E. H., J. D. Sc. XII, *1*, 1, (1929).
34. PFEFFER, J. C., JACKSON, H. C., and WECKEL, K. G., J. D. Sc. XXI, *5*, 143, (1938).
35. PALMER, L. S., J. D. Sc. V, 201, (1922)
36. RICE, F. E., and MARKLEY, A. L., J. D. Sc. V, 64, (1922).
37. NAIR, J. H., Ind. Eng. Chem. *22*, 42, (1930).
38. KOESTLER, G., Schweiz. Milch Ztg., 103, (1928).
39. KOESTLER, G., ROADHOUSE, C. L., and LÖRTCHER, Landw. Jahrb. d. Schweiz. 937, (1928).
40. KRUKOVSKY, V. N., and HERRINGTON, B. L., J. D. Sc. XXI, *5*, 142, (1938).
41. KRUKOVSKY, V. N., and SHARP, P. F., J. D. Sc. XXI, *11*, 671, (1938).
42. ROGERS, L. A., U. S. Dept. Agr. B. A. I. Bul. 57, (1904).
43. ROGERS, L. A., BERG, W. N., and DAVIS, B. J., U. S. Dept. Agr. B. A. I. Bul. 189, (1910).
44. KAY, H. D., Zum 70. Geburtstag v. Robert Burri, 34, (1937).
45. BABCOCK, S. M., and RUSSELL, H. L., Wis. Agr. Expt. Sta. Ann. Rept. 161, (1897).
46. THATCHER, R. W., and DAHLBERG, A. C., J. Agr. Res. XI, 9, (1917).
47. GILLET, cited by GRIMMER, W., Chemie u. Physiologie der Milk, 208, (1910).
48. SPITZER, GEO., and TAYLOR, M. C., J. D. Sc. VII, *3*, 234, (1924).
49. PALMER, L. S., and MILLER, M. M., J. D. Sc. IX, *3*, 272, (1926).
50. SMITH, J. A. B., and DASTUR, N. N., Biochem. Jour. XXXII, *10*, 1868, (1938).

CHAPTER XXII

WHOLESOMENESS, FOOD VALUE, AND BIOLOGICAL PROPERTIES OF BUTTER

Sanitary Purity and Wholesomeness.—The degree of freedom of butter from products of decomposition and from microorganisms harmful to man, must of necessity vary greatly with the purity of the raw material, the milk and cream from which the butter is made, and with the process used for manufacture. And these factors in turn are subject to wide variations.

Whole milk creameries which receive their milk in fresh condition and have exclusive control over the cream, are in a position to prevent undesirable fermentations that render both cream and butter unpalatable, though not necessarily unwholesome. All creameries receiving cream instead of milk, depend to a large extent on the cream producer for the quality and degree of freshness of their raw material.

Most gathered-cream creameries receive their cream in more or less sour condition, the degree of acidity varying from sweet cream with no more than .2% acid, to sour cream with an acidity of from .2% to approximately 1.5%, and averaging about .5% acid. The acidity of the cream naturally varies with such conditions as location, season of year, facilities and inclination of the producer to cool the cream on the farm, and frequency of delivery or shipment.

Aside from the production of acid in the cream, other fermentations may and frequently do set in, which tend to lower the quality of the cream and the flavor, keeping quality and market value of the butter. The great majority of these fermentations, while objectionable from the standpoint of the market value of the butter, are so far as is known, entirely harmless as regards the health of the consumer. In rare cases isolated cans of cream may contain putrefactive matter. The shipment and acceptance of such cream is unlawful in most states. Such cream is rejected or discarded by the creameries or confiscated by health authorities.

In the process of manufacture efforts are made to minimize the effect of conditions which tend to jeopardize the keeping

quality of the product. These efforts consist largely in standardizing the acidity of the cream by the use of a neutralizer, in pasteurization to remove objectionable micro-organisms, in using a pure culture starter of lactic acid bacteria and flavor organisms, and in washing the butter with pure water to eliminate as much as possible of the buttermilk.

None of these steps in the process of manufacture are objectionable as concerns the health of the consumer. The neutralizer most commonly used is milk of lime which in itself is a necessary food element of man, and if it were taken up by the butter in appreciable quantities could do no possible harm. However, analyses have shown that butter made from cream in which the acidity was standardized by the use of lime, contained no appreciable increase in lime content over butter made from cream not so treated. Soda neutralizers, such as sodium bicarbonate and sodium carbonate, or mixtures of the two, form soluble salts in the sour cream, which largely pass off with the buttermilk. But even if present in the butter, are above reproach from the standpoint of the wholesomeness of the butter.

Chlorine products, especially of the chloramine-T type, are occasionally added to the cream in efforts to expel objectionable weed flavors, such as wild onion, garlic and Frenchweed flavors. For ethical reasons the addition to a food product of chemicals, other than acid neutralizers is obviously objectionable and should be avoided. From the standpoint of the wholesomeness of the butter, their effect is negligible, the free chlorine being dissipated before the cream reaches the churn. The health angle here is comparable to that of chlorinated drinking water.

Pasteurization of the cream has no known effect on the digestibility of the butter. The use of starter and the practice of cream ripening tend to improve the wholesomeness of butter, since lactic acid and lactic acid bacteria aid in digestion and assist in keeping the intestinal tract in a healthy condition. The washing of the butter with pure water, aside from freeing the butter from much of the elements of buttermilk, such as curd and lactose, that yield most readily to decomposition, assists in removing any soluble decomposition products if such products are present. American butter contains no preservatives of any kind. The addition of preservatives to butter is prohibited by the Federal Pure Food and Drug Act of 1906.

It may, therefore, be safely stated that commercial butter

is devoid of ingredients, such as decomposition products derived from the cream, or chemicals added in the process of manufacture, that have any known harmful effect on the health of the consumer, nor have any of the natural constituents of the butter been changed by the process of manufacture, in a manner that would detract from the wholesomeness of the finished product.

The number of bacteria that may be expected to be found in sour, farm-skimmed cream, such as is received at the average gathered cream creamery, is shown in Table 72.

Efficient pasteurization, either by the vat process at 145° F. or higher for 30 minutes, or by the flash process at 180° F. or higher, or at intermediate temperatures and periods of exposure properly adjusted, possesses a germ killing efficiency of approxi-

Table 72.—Germ Killing Efficiency of Pasteurization[1]

Vat Pasturization at 145° F. for 20 Minutes.

Experiment No.	Acidity in Cream %	Raw Cream Bacteria Per c.c.	Temperature and Time of Holding	Pasteurized Cream Bacteria Per c.c.	Germ-killing Efficiency %
13	.42	820,000,000	145° F. 20 min.	526,000	99.936
14	.35	440,000,000	145° F. 20 min.	438,000	99.900
15	.66	390,500,000	145° F. 20 min.	21,600	99.994
16	.48	490,000,000	145° F. 20 min.	146,500	99.970
17	.34	530,000,000	145° F. 20 min.	325,000	99.939
18	.60	600,000,000	145° F. 20 min.	77,000	99.987
19	.47	328,000,000	146° F. 20 min.	30,050	99.991
20	.46	111,000,000	145° F. 20 min.	151,000	99.864

Flash Pasteurization at 180° F.

Experiment No.	Acidity in Cream %	Raw Cream Bacteria Per c.c.	Exposure Used Flash	Bacteria Per c.c.		Germ-killing Efficiency %
				Pasteurized Cream	Cream After Cooling	
1	.47	254,500,000	180° F.	5,450	6,600	99.998
2	.56	352,000,000	180° F.	2,750	4,400	99.999
3	.44	620,000,000	180° F.	3,100	2,650	99.999
4	.54	515,000,000	180° F.	4,400	85,000	99.999
5	.57	265,000,000	180° F.	3,800	23,800	99.999
6	.45	495,000,000	180° F.	1,150	1,250	99.999
7	.54	570,000,000	180° F.	4,800	15,500	99.999
8	.42	820,000,000	180° F.	17,650	18,200	99.998

mately 99.99%. With this germ killing efficiency there is usually an almost complete absence of yeasts and molds in the pasteurized cream.

Fig. 110 and Fig. 111 are photographs of agar plates prepared from raw cream and from the same cream pasteurized. These show definitely the marked reduction in bacteria resulting from efficient pasteurization. The bacterial count of the raw cream was 180 million and the count of the same cream after pasteurization was 4,000.

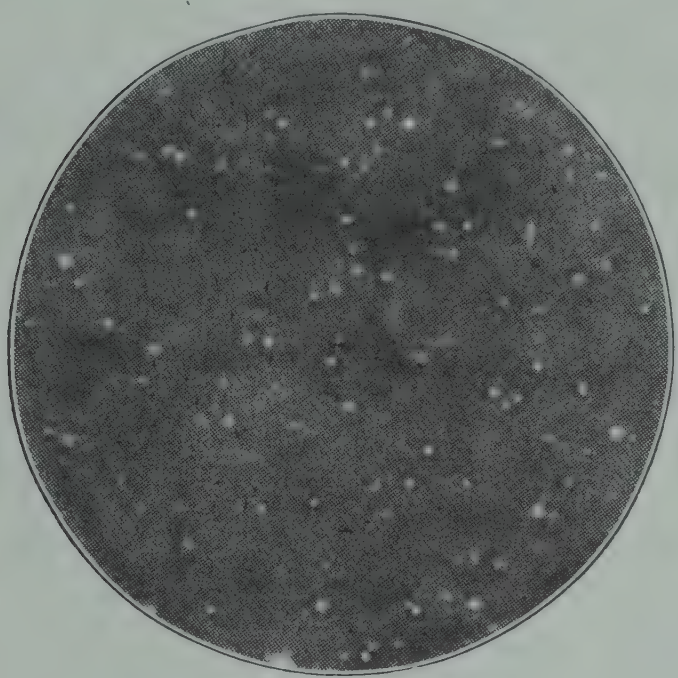


Fig. 110. Raw Cream
Dilution 1 : 1,000,000

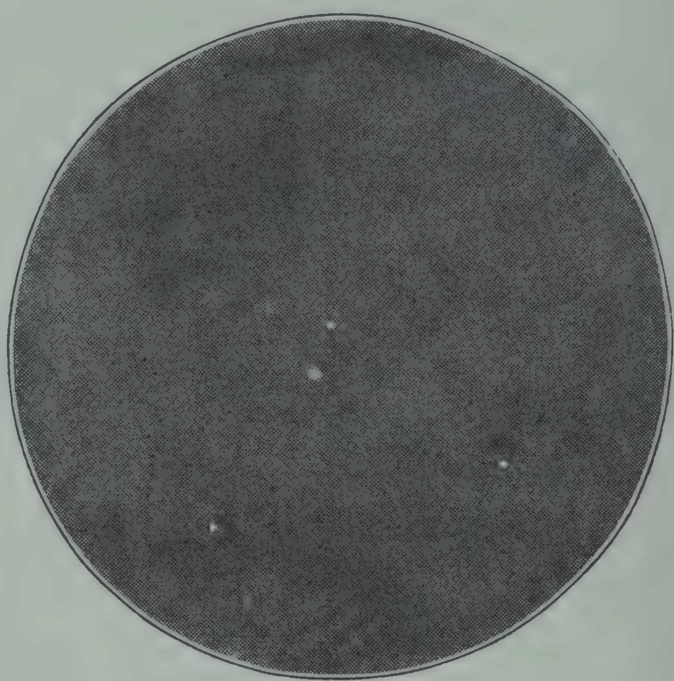


Fig. 111. Pasteurized cream
Dilution 1 : 1,000

Plate counts showing germ-killing efficiency of pasteurization

Freedom from Germs of Disease.—Milk is capable of becoming the carrier of germs of bovine diseases infectious to man, such as tuberculosis, foot and mouth disease, undulant fever, milk sickness, and of micro-organisms and viruses of human diseases, such as tuberculosis, typhoid fever, scarlatina, diphtheria, septic sore throat, etc. The question is, therefore, not only pertinent but very important, "Does butter made from milk and cream infected with these diseases, contain the disease germs or viruses, and if so, is it capable of causing the disease among the consuming public?"

Experimental data of considerable magnitude are recorded, which unmistakably show that cream, produced either by gravity creaming or by centrifugal separation of milk infected with bacillus tuberculosis, also contains this organism and that butter made from such cream, when inoculated into guinea pigs, pro-

duced the disease and caused the animals to die from generalized tuberculosis.

Thus, Moore[2] showed that when milk containing tubercle bacilli was separated by centrifugal force, both the skim milk and the cream harbored these bacilli. Inoculation of the skim milk and cream, respectively, into guinea pigs caused them to die with the disease in 24 to 60 days. Burri and Griflinger[3] demonstrated that the products of tubercle-infected whey, separated by centrifugal force for the purpose of making whey butter, caused tuberculosis in guinea pigs. Schroeder[4] reported that when cream was separated from milk infected with Bacillus tuberculosis, either by gravity or by centrifugal force, it also contained these germs, and that butter made from such cream contained the tubercle bacillus as determined by inoculation into guinea pigs. Broers[5] found that tubercle bacilli will live three days in milk, even when it has undergone changes that make it unfit for use as food, and twelve days in buttermilk, and that they remain virulent three weeks in butter. Cornet[6] reported that Laser could find no live bacilli in butter after twelve days, that Heine found that all tubercle bacilli eventually die in butter and that their maximum life in it is thirty days, that Gasperini found a reduction of virulence after thirty days, though the bacilli were still alive after 120 days, and that Dawson did not observe a reduction of virulence until after the passage of three months, and claims to have produced tuberculosis in a guinea pig by inoculating it with butter eight months old. Schroeder and Cotton[7] stated that living tubercle bacilli will retain their infective properties for at least 160 days in salted butter when kept without ice in a house cellar. They fed over 60 guinea pigs, from time to time up to 100 days, with butter from a cow infected with tuberculosis. With the exception of five that died prematurely, and one that was killed, all died with generalized tuberculosis. Swithinbank and Newman[8] tested 498 samples of market butter (in England) and found 76 samples or 15.2% to contain tubercle bacilli. Schroeder[4] stated that since salt has distinct though weak germicidal properties, tubercle bacilli in heavily salted butter may live only a short time, while in unsalted butter they may live and remain virulent indefinitely. No appreciable attenuation of tubercle bacilli occurred in ordinary salted butter in 49 days, even though the butter had become rancid and moldy. They were still alive and capable of causing

rapidly fatal tuberculosis in guinea pigs after 133 days. Mohler, Washburn and Rogers[9] showed that 153 days of cold storage under ordinary commercial conditions, is not long enough to kill the tubercle bacilli in butter and they further stated that constant storage at an icy temperature does not destroy the virulence of the dangerous tubercle bacilli if contained in butter, and that no dependence should be placed on the action of the salt that is added to butter, as an agent in the destruction of tubercle bacilli, since its action is very slight at best. The bacilli retained virulence in salted butter for six months.

The findings quoted in the preceding paragraphs show considerable variations in the length of time butter infected with Bacillus tuberculosis retains virulent bacilli. However, this evidence shows conclusively that butter made from tubercle-infected milk or cream harbors these bacilli and is capable of spreading the disease. It further shows that separation of the milk by centrifugal force does not insure freedom from these bacilli in the cream and that the salt in butter does not destroy their virulence.

The results of the study of the heat resistance of pathogenic bacteria that may be present in milk, by the foremost bacteriologists and pathologists, show that the tubercle bacilli (Mycobacterium tuberculosis) are more resistant to heat than any of the other germs of milk-borne diseases, likely to be found in milk. The early work of Theobald Smith in 1899,[10] of Russell and Hastings in 1900,[11] and of Rosenau in 1912,[12] showed that exposure to a temperature of 60° C. (140° F.) for 20 minutes is adequate to destroy the tubercle bacilli, as well as other pathogenic organisms, thereby indicating that butter made from properly pasteurized cream, may be expected to be free from the germs or viruses of such diseases as tuberculosis, typhoid fever, undulant fever, scarlet fever, diphtheria, dysentery, septic sore throat, etc.

Thus, Rosenau[12], as the result of his own extensive investigations, and in summarizing the work of other investigators of acknowledged authority states, that it is justifiable to assume that ordinary market milk pasteurized by heating to 60° C. (140° F.) for 20 minutes, would be safe for human use by mouth, so far as tubercle bacilli are concerned; that the virus of foot and mouth disease is killed with certainty at a temperature of 60° C. for twenty minutes; that heating milk to 60° C. for two min-

utes destroys the typoid fever germs; that the diphtheria bacillus and the cholera vibrio die at a comparatively low temperature (55° to 60° C.); that the dysentery bacillus is killed by an exposure to 60° C. for ten minutes; that the infective principle of Malta fever, or undulant fever, M. melitensis (Br. abortus), is destroyed at 60° C.; and that a temperature of 60° C. for twenty minutes is sufficient to destroy the virus of scarlet fever, streptococci and other pathogenic organisms. He therefore concludes that milk heated to 60° C. and maintained at that temperature for twenty minutes, may be considered safe so far as concerns its ability to be a carrier of the disease organisms mentioned. Schroeder and Cotton[7] state that the minimum effective temperature of pasteurization that will destroy the non-spore bearing disease germs is 60° C. for twenty minutes. Mohler, Washburn and Rogers[9] recommended heating the cream to 60° C. for twenty minutes. Ayres[13] reports that such disease producing bacteria as Bacillus tuberculosis, Bacillus typhosus, Bacillus diphtheria and the dysentery bacillus are destroyed when heated to 140° F. for twenty minutes and that the same process safeguards the public against the virus of scarlet fever. Pease[14], who conducted an extensive investigation on the efficiency of the holding process of pasteurization as regards the destruction of the germs of tuberculosis, typhoid fever and diphtheria in milk, found that the use of a temperature of 147° F. for a fraction of a minute and the additional holding of the heated milk for thirty minutes, at temperatures ranging from 143° to 145° F. is sufficient to insure the total destruction of these germs, even when present in milk in large numbers. His experiments were made with commercial equipment, under strictly commercial conditions, and with milk heavily inoculated with these disease organisms.

Regarding Brucella abortus (the germ of undulant fever) Park et al reported that in milk heated to 60° C. (140° F.) for 10 minutes, or to 61.1° C. (142° F.) for 7.5 minutes, or to 62.8° C. (145° F.) for 5 minutes, these organisms were killed. Wilkie et al[16] inoculated daily aliquots of raw milk and of milk pasteurized by the holding process (145 to 147.5° F.), into duplicate guinea pigs twice weekly. They found viable tubercle bacilli in 70% and Br. abortus in 38% of the samples of the raw milk. The pasteurized milk samples were uniformly negative to both tests.

In the case of flash or continuous pasteurization Mohler et al[9] recommended 80° C. (176° F.) momentary exposure, as a reliable means of effectually destroying all tubercle bacilli. Marshall,[7] held that milk should be heated to 85° C. (185° F.) momentarily, in order to insure freedom from tubercle bacilli.

Summary of the Status of Butter Relative to Freedom from Germs of Disease.—It has been conclusively shown that milk may and frequently does contain germs of diseases infectious to man, that cream separated from such milk also contains the organisms and that butter made from infected cream may likewise be contaminated. It was further pointed out that disease germs in butter remain alive and virulent for a sufficient period of time to make such butter a dangerous carrier of disease. Neither the acid nor the salt concentration in butter is sufficient to destroy the organisms, nor does cold storage eliminate them.

In addition, the fact should not be overlooked that a large portion of the annual butter production comes from sections of the country where dairying is only a side line of farming, where the herds are small and scattered over so wide a territory, as to be beyond the reach of sanitary inspection and control. The extent of actual contamination of the cream supply from these miscellaneous sources, with disease organisms, may be no greater than that of cream from the more intensified dairy sections, but the possibilities are certainly more unlimited.

In view of the facts and conditions above referred to, the necessity of pasteurization of cream for butter making, as a guarantee of the wholesomeness of butter and a dependable protection of the health and life of the butter consumer, is obvious. It was shown by the work of Dahlberg[18] and of many other investigators, that the standard temperatures and time exposures used in cream pasteurization for butter making (145° F. or higher for 30 minutes, or flash heatings to 180° F. or higher, or intermediate temperature-time combinations of equal or greater germ-killing efficiency), provide even a greater margin of safety than the accepted standard for the pasteurization of milk. These temperatures and time exposures definitely destroy the organisms of any of the pathogenic species likely to be found in milk or cream, such as the germs of tuberculosis, typhoid fever, undulant fever, diphtheria, scarlet fever, septic sore throat, staphylococcus poisoning, etc.

Butter made from properly pasteurized cream may be expected, therefore, and in fact is, free from disease organisms with which the cream may have been infected. To be sure, the possibility of reinfection after pasteurization does exist, but the usual plant practices and sanitation render this danger exceedingly remote. In order for cream pasteurization to insure dependable freedom from pathogenic organisms in the resulting butter, it must be performed in an efficient manner, that will subject all the cream and foam to the intended temperature-time exposure. This is important.

In flash pasteurization there is need of recirculating the cream through the pasteurizer until the cream at the outlet of the pasteurizer registers the full, intended temperature. The temperature must be maintained uniformly during the entire run. Crowding of the machine beyond its capacity decreases the pasteurizing efficiency and must be avoided. Where the heating is done by injecting direct (live) steam into the cream, the system must allow for ample impingement of steam and cream to insure actual absorption of the full, intended temperature by the particles of the cream.

In vat pasteurization, all the cream, including the foam on the surface and the cream in the gate valve and nipple, if any, must be heated to the full pasteurizing temperature. The results of Murray, McNutt and Purwin[19], who tested the effect of vat pasteurization of milk inoculated with a culture of Brucella organisms, found when using a "standard pasteurizing outfit," that an exposure of 3 minutes at a temperature of 62° to 63° C. (143.6 to 145.4° F.) was sufficient to destroy the Brucella organisms. However, with the vat lid open, a much longer time exposure to this temperature was required and the results were irregular and uncertain, viable organisms being recovered from the foam even after 30 minutes of pasteurization. These investigators further point out the necessity of a flush gate valve. When using an ordinary faucet outlet, viable organisms were obtained from the outlet after 30 minutes of pasteurization, while with the outlet closed by a stopper on the inside, no living organisms remained after 3 minutes' exposure.

While the number of epidemics of disease definitely traced to infected butter is so small that it may appear negligible, the ever-present possibility of infection compels the pasteurization of cream for butter making in the interest of public health. The

creamery that makes its butter from raw cream is a menace to the consumer and a detriment to the industry. In some of the states the pasteurization of cream for butter making is compulsory. Accurate data regarding the practice of pasteurization by creameries is lacking. A general survey suggests, however, that pasteurization in butter factories is almost universal and that the creameries that do not pasteurize are few in number. With proper attention to the precautions required for efficient pasteurization, the great bulk of American creamery butter may be expected to be free from viable germs and viruses of diseases infectuous to man.

Most of the farm dairy butter, however, is made from raw cream. If such cream is free from disease germs, and the water used for washing the butter is bacteriologically harmless, such butter may be expected to be equally safe as the general run of factory-made butter. Yet, like farm-peddled milk which is rarely pasteurized, farm-made butter is no guarantee as to its safety to the consuming public.

Digestibility and Caloric Value of Butter

Digestibility.—The digestibility of butter, as based on the completeness of its utilization, or on its loss in digestion, is very high. It is similar to that of products containing other fats in about the same amount. Thus Luhrig[25] found the coefficient of digestibility to be 97.86% for butter and 97.55% for oleomargarine.

The coefficient of digestibility of butter fat, or the percentage assimilated of that consumed, as determined by various investigators and assembled by Langworthy and Holmes,[28, 29] is as follows:

Table 73.—Digestibility of Butter Fat

Investigator	Fat assimilated %	Investigator	Fat assimilated %
Rubner[20]	96.3	Huldgren & Landergren[24]	95.4
Rubner[20]	97.3	Luhrig[25]	96.0
Malfatti[21]	97.7	Luhrig[25]	97.0
Mayer[22]	98.0	Wibbins & Huizenga[26]	97.3
Mayer[22]	97.0	Wibbins & Huizenga[26]	96.5
Bertarelli[23]	94.0	Von Gerlach[27]	97.0
		Langworthy & Holmes[28]	97.0

Langworthy and Holmes[29] show the following comparative coefficients of digestibility, with allowance for metabolic products, for animal fats and vegetable fats:

Table 74.—Digestibility of Different Fats

Animal Fats	Coefficient of Digestibility %	Vegetable Fats	Coefficient of Digestibility %
Butter Fat	97.0	Peanut oil	98.3
Lard	97.0	Sesame oil	98.0
Chicken fat	96.7	Cocoanut oil	97.9
Goose fat	95.2	Olive oil	97.8
Fish fat	95.2	Cottonseed oil	97.8
Egg yolk fat	93.8	Cocoa butter	94.9
Beef fat	93.0		
Mutton fat	88.0		

As regards digestibility, however, butter is probably superior to most other fats. Sherman[30] points out that fats in general retard the secretion of gastric juice and tend to make the food stay longer in the stomach. He shows that in so far as the rapidity with which a meal passes from the stomach to the intestines may serve as a criterion of the ease of digestion, the eating of fats appears to retard the process. This retardation is more pronounced the higher the melting point of the fat. Langworthy and Holmes conclude that butter fat may be considered more completely assimilated, than any of the other animal fats which they considered in their investigation. This statement refers to lard, beef fat, and mutton fat.

Caloric Value.—The caloric value of butter varies with its composition. It depends largely on the per cent of fat contained in butter. The curd content is fairly uniform and is usually assumed to be about 1%.

The caloric value should be calculated only on the digestible nutrients. The coefficients of digestion in butter average about 94.1% for the curd, or protein, and 97% for the fat. The digestible nutrients in butter with varying percentages of fat, then, are approximately as follows:

Table 75.—Digestible Nutrients in Butter

Butter with 80% fat

$$1\%\ \text{protein}\ \frac{1. \times 94.1}{100} = .941\%\ \text{digestible protein}$$

$$80\%\ \text{fat}\ \frac{80 \times 97}{100} = 77.600\%\ \text{" fat}$$

$$\text{Total digestible nutrients} = 78.541\%$$

Butter with 82.5% fat

$$1\%\ \text{protein}\ \frac{1. \times 94.1}{100} = .941\%\ \text{digestible protein}$$

$$82.5\%\ \text{fat}\ \frac{82.5 \times 97}{100} = 80.025\%\ \text{" fat}$$

$$\text{Total digestible nutrients} = 80.966\%$$

Butter with 85% fat

$$1\%\ \text{protein}\ \frac{1. \times 94.1}{100} = .941\%\ \text{digestible protein}$$

$$85\%\ \text{fat}\ \frac{85 \times 97}{100} = 82.450\%\ \text{" fat}$$

$$\text{Total digestible nutrients} = 83.391\%$$

From these figures may be calculated the caloric value of butter of different compositions. A calorie (large calorie) is the amount of heat required to raise the temperature in 1,000 grams of water 1° C. The caloric value of protein is 4100, and that of fat is 9300. 1,000 grams are equal to 2.2 pounds, hence the caloric value of one pound of protein is $\frac{4100}{2.2} = 1863$, and the caloric value of one pound of fat is $\frac{9300}{2.2} = 4227$.

The caloric value of one pound of butter containing 80%, 82.5% and 85% fat, respectively, therefore is as follows:

Table 76.—Caloric Value of Butter

Butter with 80% fat

$$1\%\ \text{protein}\ \frac{.941 \times 1863}{100} = 18\ \text{Calories}$$

$$80\%\ \text{fat}\ \frac{77.6 \times 4227}{100} = 3{,}280\ \text{"}$$

$$\text{Total calories} = 3{,}298\ \text{"}$$

Butter with 82.5% fat

$$1\%\ \text{protein}\ \frac{.941 \times 1863}{100} = 18\ \text{Calories}$$

$$82.5\%\ \text{fat}\ \frac{80.025 \times 4227}{100} = 3{,}382\ \text{"}$$

$$\text{Total calories} = 3{,}400\ \text{"}$$

Butter with 85% fat	1% protein	$\frac{.941 \times 1863}{100}$	=	18 Calories
	85% fat	$\frac{82.45 \times 4227}{100}$	=	3,485 "
	Total calories		=	3,503 "

VITAMINS

Importance of Vitamins.—Important discoveries by eminent nutrition experts have revealed the presence of substances of food origin, that are essential for the normal function of animal life. Extensive feeding experiments have shown that, before complete growth can occur in a young animal, and for prolonged maintenance and for the prevention of certain diseases, the diet must contain, in addition to proteins, carbohydrates, fats and mineral salts, accessory substances, generally known as vitamins. Deficiency or absence of these vitamins in the diet causes abnormal physiological conditions. It is the effect of their deficiency, resulting in physiological disturbances and pathological conditions, that has lead to their original discovery, to recognition of their functions, and to appreciation of their nutritional importance.

As the result of more recent study progress has been made in identifying vitamins chemically. These efforts have resulted in the recognition of the existence of at least six vitamins distinctly different from one another in character and in their functions in the diet, namely, vitamins A, B, B_2, C, D and E. Of these, vitamins A, B and C have been chemically identified and structural formula have been proposed that are now generally accepted. Progress has also been reported relative to the identification of vitamins D and E. The present brief discussion is limited primarily to vitamins that are associated with butter fat and butter.

Vitamin A.—This vitamin is essential for normal growth, resistance to infection and disease, and for reproduction. It is needed in the diet of individuals of every age, for adults as well as for growing children. Its deficiency in the food supply stunts growth, weakens the tissues of the various organs, reducing their resistance to infection, and is conducive to the disease of xerophthalmia, an eye disease culminating in blindness.

Vitamin A is a fat-soluble substance. It was discovered in connection with milk fat. It is present abundantly in a comparatively limited list of foods, such as milk fat, the fat in egg yolk, the liver, the fats of the vital organs, cod liver oil, and leafy vegetables. It is absent in ordinary animal fats, such as lard and tallow, nor is it present in any of the vegetable fats and oils. It has been isolated in pure form, and is described to be a viscous, yellowish oil. It has been given the empirical formula $C_{20}H_{30}O$.

The discovery of the relation between carotene and vitamin A potency, by Steenbock[32, 33] in 1919, later confirmed by Euler, Euler and Hellstroem,[34] assisted in its chemical identification. Carotene, the yellow pigment in butter fat, can be converted into Vitamin A by the animal body of herbivorous animals. It thus serves as a precursor of vitamin A, and is so recognized. This should not be interpreted to the effect that all butter with high color is rich in vitamin A, but it does point in the direction that butter that is naturally very yellow, tends to contain more vitamin A than light colored butter.

The carotene and the vitamin A content of milk fat and of butter are greatly influenced by the feed of the cow, and vary, therefore, with the season of the year. It was pointed out in Chapter XXI, under "Color of Butter Fat," that the carotinoids responsible for the yellow color of butter, are most abundant in green feeds, such as succulent pasture grasses. Baumann and Steenbock[35] determined the carotene and the vitamin A contents of milk fats from mixed milk monthly for an entire year. Their results show that carotene and vitamin A are highest during the summer months and lowest during winter and early spring, as indicated in Table 77.

Similar results relative to the effect of feed on the vitamin A potency of milk fat were reported by numerous other investigators. Fraps and Treichler[36] found that the vitamin A content of milk fat from cows fed on a sole ration of cottonseed meal and hulls was only one-fifteenth of that from cows on green feed. Booth and co-workers[37] likewise reported that the quantities of carotene and vitamin A of milk fat varied with the quantity of grass or green fodder in the diet of the cow. Treichler et al[38] found cows that were on a carotene-poor, vitamin A-deficient diet, and that were producing pale butter fats low in carotene and vitamin A potency, after only 3 to 5 hours, each, on pasture.

Table 77.—The Carotene and Preformed Vitamin A Contents of Milk Fat from Mixed Milk by Months (Baumann & Steenbock)

Months	Micrograms per Gram of Fat	
	Carotene	Vitamin A
February, 1932	2.2	11
March, 1932	2.2	9
April, 1932	2.0	9
May, 1932	2.4	14
June, 1932	7.1	19
July, 1932	8.6	15
August, 1932	5.8	20
September, 1932	5.2	19
October, 1932	4.5	17
November, 1932	4.0	16
December, 1932	3.0	15
January, 1933	2.4	12
February, 1933	2.2	12
March, 1933	2.0	10

secreted yellow butter fat as high in vitamin A potency as butter fat from cows continuously on a diet adequate in carotene.

Experimental tests have shown that it is possible to maintain the high vitamin A content of summer fat throughout the year by the proper choice of winter feeds. Field-cured hay, especially when allowed to fully mature before cutting, is low in carotene content. On the other hand, artificially cured alfalfa hay and soy bean hay are rich in carotene. Gillam[39] et al concluded from their trials that relatively high proportions of vitamin A, carotene, and xanthophyll can be maintained in butter fat during the winter period of stall feeding by using artificially dried grass.

Archibald and Parsons[42] conducted feeding experiments in which a vitamin A supplement was fed to the cows. This supplement consisted of fortified cod liver oil that was incorporated in the grain mixture at the rate of 5 lbs. per ton. They reported that the vitamin A content of composite samples of milk from cows receiving the supplement was somewhat higher than that of similar samples from cows that did not receive it, but that the efficiency of transfer of the vitamin from feed to milk was very low in all cases. These investigators expressed the opinion, that the slight additional cost of grain mixtures with a vitamin concentrate is cheap insurance against troubles due to deficiency of this vitamin, particularly when the roughage is of poor qual-

ity. Wright and Smith[43] point out, however, that there is an upper limit of vitamin A potency beyond which the feeding of an additional concentrate will have no effect. They hold, therefore, that it is very questionable whether (apart from including a sufficient quantity to safeguard the animal's own health) the feeding of vitamin-rich concentrates in an attempt to raise the vitamin potency of the milk could be economically justified.

Treichler et al[38] sum up the relation of yellow color of butter fat and butter to the vitamin A content of butter as follows: "The natural yellow color of butter fat is directly proportional to the carotene content. The carotene content of butter fat is not an accurate measure of the vitamin A potency, but butter fats highly colored are probably high in vitamin A potency and butter fats of a light yellow, or nearly white color, are low in vitamin A. The relation between the carotene content and the vitamin A potency depends upon the ration of the cow, the quantities of vitamin A and of carotene stored at the beginning of the lactation period, the length of time which the ration deficient in vitamin A or carotene has been fed, the extent of such deficiency, and perhaps upon the individual cow."

The vitamin A potency of butter appears not to be affected by the treatment the cream may receive in butter manufacture. The nutrition experts who discovered vitamin A and its presence in butter fat were interested in determining definitely to what extent, if any, the processes used in butter manufacture, and the deterioration of butter oil and butter in storage, diminish or have any effect on the vitamin A potency. Butter was melted and the oil was boiled in the presence of air with live steam for several hours. It was also heated to temperatures above the boiling point under 10 to 15 pounds of pressure. To other lots of butter oil alkalies were added in the presence of air, in sufficient quantities to form soap. Feeding experiments with the resulting products showed conclusively, that none of these treatments caused any decrease in the vitamin A potency of the butter fat. These results suggest that neither the neutralization of sour cream, nor the heat treatment of cream in pasteurization or in methods for the removal of objectionable flavors and odors, have any effect on the vitamin A content of the resulting butter. Nor did the holding of butter in commercial cold storage under usual conditions and for the customary storage period, in any way diminish the vitamin A potency.

Even in butter stored for six months at 32° F. Baumann and Steenbock found no decrease in the carotene and vitamin A content of the butter. Early experiments showed that it was only when butter was exposed to air, light and heat to such an extent, and for so long a period, that it bleached, became tallowy and was no longer fit for human consumption, that its vitamin strength had decreased.

The relation of the vitamin A potency of butter made from sweet cream and from sour cream, respectively, and from oleomargarine, was determined by Hathaway and Davis.[40] In their feeding experiments with white rats the butters were fed at 0.05 cc. and 0.1 cc. levels, and the margarines were fed at 0.5 cc. and 1.0 cc. levels. Seven to nine rats were allotted to each level. All of the rats on the butter diet lived and made consistent gains in weight during the 8-week feeding periods. There was no appreciable difference in the weight gains between sweet cream butter and sour cream butter. On the oleomargarine ration all of the rats lost weight, and of the total of 75 rats, only 5 survived the 8 weeks feeding period. Additional feeding tests involving a total of 370 rats showed similar results. Most of the samples of oleomargarine contained both animal and vegetable oils. One sample was advertised as equal to butter in vitamin A content. It was fed at 0.05, 0.1 and 0.5 levels. Only two out of the 30 rats fed this sample survived the 8-week feeding period. These results show that butter made from either sweet cream or from neutralized sour cream was a good source of vitamin A. They further demonstrated that oleomargarine did not contain enough vitamin A to sustain growth and life in rats, even when fed in quantities ten times as great as were the butters.

Butter contains 80% or more of milk fat. It is, therefore, rich in fat-soluble vitamins contained in the milk fat, from which it is made. The experimental evidence cited in the foregoing paragraphs shows that the vitamin A content of summer butter and of butter made from the cream of cows fed on feeds rich in carotene and in vitamin A content, is high. Butter thus constitutes a readily available and economical source of this important vitamin. Vitamin A is the principal vitamin contained in butter.

Vitamin B.—This vitamin factor embraces a group of vitamins, the most important of which are vitamins B_1 and B_2.

Vitamin B_1.—This vitamin is water-soluble. It is necessary for growth. It stimulates appetite, aids digestion and assists in a general feeling of well-being. Its absence in the diet causes lack of appetite, leading to subnormal food consumption and resulting in drop in body temperature and death. Vitamin B_1 deficiency in the diet leads to neuritic disturbances, such as the disease known by the name beri-beri, or general paralysis.

Vitamin B_1 is present in a great variety of foods. It is present in milk and appears to be constant in amount throughout the year. It is not fully resistant to the heat of pasteurization. Limited available data suggest that commercial pasteurization destroys about 25% of the vitamin B_1 content of milk. Being water-soluble it is concentrated largely in the skim milk portion. Its content in butter is negligible.

Vitamin B_2.—This vitamin is commonly known as the anti-pellagra vitamin. It is essential for growth. Absence or marked deficiency causes a skin disease known as pellagra. In America vitamin B_2 is also called Vitamin G, so named in honor of Dr. Goldberger of the U. S. Department of Public Health Service, who discovered that vitamin B embraces both B_1 and B_2. Vitamin B_2 is water soluble and is reported to be more heat-resistant than B_1. Its content in butter appears to be negligible.

Vitamin C.—This vitamin is necessary for normal growth and health. Its absence or deficiency in the diet causes the development of scurvy and related scorbutic diseases and skin diseases, changes in the gums and teeth that produce caries and pyorrhea.

Vitamin C is present in many foods. It is especially abundant in citrus fruit. It is also contained in milk. Its concentration in milk shows considerable variation, being influenced by the feed ration of the cow. Green feeds, such as succulent pasture, increase the vitamin C content of milk.

This vitamin is sensitive to heat and oxidizing agencies, such as air and oxidizing metals (copper, iron). Recent experiments in milk pasteurization, cited by Sommer,[31] showed a destruction of 60% of vitamin C by vat pasteurization, while flash pasteurization to 161-163° F., involving quick heating and rapid cooling in aluminum equipment, did not appreciably diminish the vitamin C potency of the milk. This vitamin is water soluble. Its presence in butter is negligible.

Vitamin D.—Vitamin D is essential for normal growth and health. It is primarily associated with that part of the diet that functions in the bone or skeletal development. Its presence in the diet increases the retention and utilization in the body of calcium and phosphorous, the minerals so essential in the normal building-up of the bone structure. Deficiency or absence of Vitamin D in the diet tends to develop the disease called rickets. This disease has to do with weakness of the bony structure, enlargement of the ends of the bones and their bending due to lack of resistance to the body weight. It is the cause of bone distortion and deformity. Some of the more common outward symptoms are bow legs, knock knees, enlarged joints, abnormal conformation of the skull, defective teeth that are subject to caries, general weakness of the entire body, and subnormal vitality. It is essentially a disease of infancy and early childhood, but may also appear in adults under certain conditions or modes of living and diet.

According to observations and findings of the medical profession, the disease of rickets is today one of the most widely prevalent diseases encountered among the children of certain strata of our population. This is attributed to a generally recognized deficiency of vitamin D under our present conditions of existence, which do not provide sufficient vitamin D because of absence of exposure to sunshine that furnishes radiations of ultra-violet wave lengths. The contributing factors are the changed and unnatural mode of living brought about by our modern civilization, with its conventional clothing, indoor living habits, and atmosphere of smoke and dust. Added to these conditions is the fact that vitamin D is not available in protective amounts in the normal diet. Even milk is not an adequate source of vitamin D.

Vitamin D is fat-soluble. According to McCollum,[41] it appears to be closely associated with vitamin A, being present most abundantly in cod liver oil, milk fat and egg fat. Its presence alone, however, is not sufficient to protect against rickets. Its protective influence depends on the presence of a sufficient amount of and the proper balance between the calcium and phosphorous supply. According to more recent work there appear to be several forms of vitamin D, which differ in their effectiveness with different species of animals, and possibly with different vitamin D sources.

The vitamin D content of milk varies greatly with that of the feed of the cow and with the access of the cow to sunlight. Green feeds and properly cured (artificially dried) leafy feeds increase the vitamin D content of milk, while dry feeds and ordinary field-cured hay diminish it. The vitamin D strength of milk may be materially augmented by feeding irradiated yeast to the cow, or by direct irradiation of the milk, or by adding to the milk a small quantity of irradiated ergosterol (viosterol), or natural concentrates of this vitamin in the form of concentrates of cod liver oil or halibut liver oil.

Being fat-soluble, the vitamin D of the milk is associated with the milk fat and follows it into the butter. This vitamin is relatively heat resistant. Its potency is not diminished by cream pasteurization.

Vitamin E.—This vitamin is essential for reproduction. Its absence in the diet has been found to cause sterility in experimental rats. The sterility affects both males and females. But little is known of the chemistry and general properties of vitamin E. Feeding experiments with rats have shown that its content in milk, while very limited, is ample. It has been found abundant in wheat germ oil, and is present in sufficient quantity to prevent or cure sterility in rats, in butter fat, meats, lettuce, whole wheat, rolled oats, alfalfa and wheat germ. There appear to be no data available regarding the vitamin E content of butter, but its established presence in milk fat suggests that butter also contains this vitamin.

REFERENCES

1. Hammer, B. W., Ia. Agr. Expt. Sta. Res. Bul. 156, (1914).
2. Moore, V. A., U. S. Dept. Agr. Year Book, (1895).
3. Burri, R., and Griflinger, Landw. Jahrb. d. Schweiz, (1915).
4. Schroeder, E. C., U. S. Dept. Agr. B. A. I. Circ. 143, (1909).
5. Broers, Zeitschr. f. Tuberkulose *10*, 3, (1907).
6. Cornet, Die Tuberkulose, 2nd Ed. 122, (1907).
7. Schroeder, E. C., and Cotton, W. E., U. S. Dept. Agr. B. A. I. Circ. 153.
8. Swithinbank, H., and Newman, G., Bacteriology of Milk 221, (1903).
9. Mohler, J. R., Washburn, H. J., and Rogers, L. A., U. S. Dept. Agr. B. A. I. 20th Ann. Rept. 179, (1909).
10. Smith, Th., J. Expt. Med. IV, 233, (1899).
11. Russell, H. L., and Hastings, E. G., Wis. Agr. Expt. Sta. 17th Ann. Rept. 170, (1900).
12. Rosenau, M. J., The Milk Question, (1912).
13. Ayres, S. H., U. S. Dept. Agr. B. A. I. Circ. 184, (1912).
14. Pease, H. D., Lederle Labs., N. Y., by correspondence, (1915).
15. Park et al., Am. Jour. Public Health, *18*, 710, (1928).
16. Wilkie, J., Edwards, S. J., Fowler, A. B., and Wright, N. C., J. D. Res. VIII, *3*, 311, (1937).

17. MARSHALL, C. E., Mich. Agr. Expt. Sta. Bul. 184, (1900).
18. DAHLBERG, A. C., N. Y. (Geneva) Agr. Expt. Sta. Tech. Bul. 203, (1932).
19. MURRAY, C., McNUTT, S. H., and PURWIN, P., J. D. Sc. XV, *1*, 6, (1932).
20. RUBNER, Zeitschr. f. Biologie *15*, 1, (1879) and *16*, 1, (1880).
21. MALFATTI, SITZBER, K. Akad. Wiss. III, 5, (1884).
22. MAYER, Landw. Versuchsst. *29*, (1883).
23. BERTARELLI, Riv. Ig. e. Sanit. Pub. 9, 14 and 15, (1898)
24. HULDGREN & LANDERGREN, Skand. Arch. Pysical, *2*, 4 and 5, (1890).
25. LUHRIG, Zeitschr. f. Untersuch. Nahr. u. Genussm. *2*, 6 and 10, (1899).
26. WIBBINS and HUIZENGA, Pflüger's Arch. Physiol. *83*, 10, 11, 12, (1901).
27. VON GERLACH, Zeitschr. Phys. u. Dietet. *12*, 2, (1908).
28. LANGWORTHY, C. F., and HOLMES, A. D., U. S. Dept. Agr. Bul. 507, (1917).
29. LANGWORTHY, C. F., and HOLMES, A. D., U. S. Dept. Agr. Buls. 310, (1915) ; 505, (1917) ; 510, (1917).
30. SHERMAN, H. C., Food Products 390, (1916).
31. SOMMER, H. H., Market Milk and Related Products, (1938).
32. STEENBOCK, H., Science *50*, 353, (1919).
33. STEENBOCK, H., and BOUTWELL, B. W., J. Biol. Chem. *41*, 81, (1920).
34. EULER, B. V., EULER, H., and HELLSTROEM, H., Biochem. Zeitschr. *203*, 370, (1928).
35. BAUMANN, C. A., and STEENBOCK, H., J. Biol. Chem. *101*, 547, (1933).
36. FRAPS, G. S., and TREICHLER, R., Tex. Agr. Expt. Sta. Bul. 477, (1933).
37. BOOTH, R. H., KON, S. K., DANN, W. G., and MOORE, T., Biochem. Jour. *27*, 1189, (1934).
38. TREICHLER, R., GRIMES, M. A., and FRAPS, G. S., Tex. Agr. Expt. Sta. Bul. 513, (1935).
39. GILLAM, A. E., Biochem. Jour. *28*, 79, (1934).
40. HATHAWAY, I. L., and DAVIS, H. P., Nebr. Agr. Expt. Sta. Res. Bul. 79, (1935).
41. McCOLLUM, E. V., The Newer Knowledge of Nutrition, (1922).
42. ARCHIBALD, J. G., and PARSONS, C. H., Mass. Agr. Expt. Sta. Bull. 357, (1939).
43. WRIGHT, N. C., and SMITH, J. A. B., Jour. Ministry Agr., XLVI, *6*, 559, (1939).

CHAPTER XXIII

BUTTER DEFECTS

Classification of Defects.—Butter is subject to, and may possess or develop any one or more of a great variety of defects. The defects that may be found in butter are of diverse nature and origin. According to their general nature these defects are classified under three main groups; namely, those of flavor and aroma, of body and texture, and of color.

DEFECTS IN FLAVOR AND AROMA

The defects belonging to this group are by far the most important quality defects of butter. The unique, pleasing flavor inherent in fresh butter properly manufactured from a good grade of cream, constitutes a fundamental asset in demand creation, and freedom from objectionable off-flavors is a deciding factor in consumer acceptance. Flavor defects, more than any other faults of butter, affect butter consumption adversely, penalizing the entire industry, while their absence makes for increased consumption, and thus provides an essential stimulus for an active and prosperous commerce in butter.

Mechanism of Flavor Determination.—Flavor proper is essentially determined by the sense of taste, centered in the flavor-registering elements of the tongue, known as the taste buds. The customary means of recognizing and designating the various shades and gradations of taste sensations is that of comparing them with the tastes of known nature, such as the generally recognized, primary taste impressions of sweet, sour, salt and bitter.

Aroma is primarily recognized by the sense of smell. In addition, the aroma may, and usually does modify, supplement or intensify the flavor. In fact, the taste sensation is often subordinate to and largely controlled by the aroma. Thus, the entire inner surface of the mouth, the mucous membranes of the connecting canals to the nose, as well as the nose itself, enter in and contribute to the taste sensation. The shaping of these composite taste impressions is further assisted by the

secretions of the salivary glands of the mouth and the moisture in the nasal passages, which provide means for accelerated solution and diffusion of the components of butter.

The complexity of taste sensations thus registered, inevitably augments the variety of shades and gradations of taste, and complicates efforts to provide accurate designations for the great variety of off-flavors. This has led to the preference and practice of naming the various butter flavors in accordance with their known, or most likely origin, such as cowy flavor, feed flavor, weed flavor, woody flavor, metallic flavor, etc.; or in the case of flavors of bacterial origin or resulting from chemical reactions, of using designations of comparable, well-known flavors recognized in other substances or food products, such as rancid flavor, tallowy flavor, fishy flavor, putrid flavor, etc.

As indicated above, the possible flavor defects of butter are numerous and of great variety. They may be due to direct absorption by cream or butter, of objectionable flavors and odors from other substances or products, or to bacterial fermentation, or to enzymotic or chemical reactions, or to combinations of two or more of these causes. They may have originated in the cream during its production, handling and transit, or been produced during manufacture, or developed in butter after manufacture, or they may be the result of a combination of such conditions as quality of cream, method of manufacture, and conditions of storage. The same off-flavor may be produced independently by several different factors, or combinations of factors, and the same factor may cause several different off-flavors.

The complex interrelation of many of these flavor defects and their causes emphasizes the futility of attempting to group them for consideration according to their causes, and suggests the following grouping as the most practicable sequence for discussion: 1) Flavor defects most likely due to off-flavors in the cream, 2) flavor defects that may develop during manufacturing due to faulty plant methods, and 3) flavor defects that may develop after manufacture.

1. FLAVOR DEFECTS MOST LIKELY DUE TO OFF-FLAVORS IN THE CREAM

Feed and Weed Flavors and Odors.—To this group of flavor defects of butter belongs the multitude of flavors and odors characteristic of the feeds and weeds to which the cows

have access. With but a few exceptions, the objectionable feed and weed flavors that appear in the freshly drawn milk are more or less readily soluble in or absorbed by the milk fat. They, therefore, are often more intense in the cream than in the original milk, and they reappear in the butter churned from such cream.

The contamination of the milk with the flavor and odors, characteristic of the feed which the cows eat, may occur through diverse channels. The flavor substance may be present in the feed as such, and is absorbed into the milk from the animal body, either through vehicle of digestion, or by inhalation of the feed odors; or the flavor substances present in milk from cows feeding on certain plants may have been produced from such feeds by way of animal metabolism; or the stable air may be impregnated by the feed odor, causing this odor to be absorbed by the milk during milking and handling in the stable atmosphere; or the milk may become contaminated with species of bacteria of the respective feed flora that are capable of producing the characteristic feed flavors and odors.

The extent to which feed and weed flavors may and do impregnate the butter varies with such factors as character of feed, individuality and condition of the cow, amount of feed, time when fed relative to the next milking, and treatment of milk and cream.

Feeds.—Some feeds, even when fed in large quantities and without restriction as to time of feeding, do not have any objectionable effect on the flavor of milk. This is true with most of the dry feeds, such as hay and concentrates. It applies to such green feeds as blue grass pasture, Sudan pasture and green corn. Babcock[1] found that green corn may be fed to dairy cows at the rate of 25 pounds at any time without producing objectionable flavors or odors in milk, and Roadhouse and Henderson[2] reported that wheat bran, fed in quantities as high as 7½ pounds, actually improved the flavor of milk, and that other dry concentrates, such as rolled barley, coconut meal, soybean meal, cottonseed meal and dried beet pulp, when fed in normal quantities from one to two hours before milking, did not give milk an objectionable flavor.

The majority of other green feeds, when fed in considerable quantity a short time before milking, do impregnate the milk

with more or less intense off-flavors, but may safely be fed immediately after milking and up to about five hours before the next milking. This is the case with green alfalfa, alfalfa hay, corn silage, clover hay, sweet clover, wheat pasture, green barley, wild oats and diverse roots, such as turnips, carrots, potatoes, also cabbage and beet tops. In the case of green sweet clover, which taints the milk when fed immediately before milking, Dice[3] suggests prevention by the practice of keeping the cows "filled up," which means keeping them on pasture all of the time. He argues that, when the cows are sent out to pasture in the morning, they get their fill and eat little, if anything, later in the afternoon. A similar principle may be involved in the findings of Riddet and co-workers,[4] who observed that the poorer the pasture the more intense the feed flavor, and the more grassy the pasture the milder the feed flavor. On grassy pasture the cows satisfy their needs long before the next milking, while on a poor pasture they may have to graze all day up to milking time in order to satisfy their feed requirements.

The foregoing discussion emphasizes that objectionable feed flavors caused by the feeds listed in the above paragraph may be readily avoided by feeding immediately after milking and only up to within five hours of the next milking. In addition, the feeding of frozen, decayed or moldy feeds, such as frozen beet tops, sour brewers' grains and distillery slops, decayed roots, and moldy silage, tends to yield objectionable flavors in the milk and should be avoided.

Weeds.—The feed flavors that are most damaging to the flavor and market value of butter are those derived from obnoxious weeds, such as wild onion, garlic, Frenchweed, weeds associated with peppergrass, and the like. In this case the cause lies in pastures infested with these weeds, the characteristic objectionable flavor essences of which are so intense and so potent, when eaten by the cows at any time between milkings, that they taint the dairy product intensely.

Wild onions and garlic are often the first green feed available on early pasture in the spring and, especially after a dry summer, they are the last green feed on late pasture in the fall. Onion and garlic flavor in butter, therefore, is the greatest menace in the spring and occasionally in the fall of the year. Their prevalence is particularly serious in years when the condi-

tion of the pastures is otherwise poor. Frenchweed and weeds associated with peppergrass appear in midsummer. Their rank growth tends to crowd the desirable pasture grasses. They are extremely hardy. Drought conditions that are destructive to normal feed grasses favor their growth and spread.

Butter containing the flavors of these obnoxious weeds is disastrously penalized on the market. Their presence is a heavy drain on the industry and causes heavy financial losses annually. Successful prevention lies in eradication of these weeds from the pastures. Definite and successful methods have been worked out by the U. S. Department of Agriculture and by the experiment stations in the several states. This service is available to the farmer. With the right spirit of co-operation on the part of the farmers of the community, eradication is possible of accomplishment in a surprisingly few seasons of intensive effort. In order to give the importance and the urgency of eradication, for the producer's own benefit, a real meaning, there is need, above all, of active and sustained co-operation on the part of the creamery, in the form of accurate grading and equitable quality-paying, performed fearlessly and without let-up.

Possibilities of Removal of Feed and Weed Flavors from Milk and Cream.—The constructive and permanent elimination of feed and weed flavors in butter lies in prevention by the producer on the farm. It is a problem of farm management. Expulsion of these flavors in the handling of milk and cream on the farm and in the factory by remedial processes should not have to be resorted to.

In the case of minor feed flavors only, aeration on the farm and the various steps in the normal process of manufacture may assist in minimizing or eliminating them. For the removal of the flavors of obnoxious weeds, however, much more severe treatment is necessary, if such removal is possible at all. The methods for such treatment are discussed in detail in Chapter XII on "Treatment of Cream for the Removal of Objectionable Flavors and Odors."

Cowy and Barny Flavor.—This type of flavor defect suggests contamination with manure, or stable air, or both. The objectionable flavor in butter is frequently very pronounced, particularly in farm dairy butter of poor quality. The cowy flavor may be due to cows with unclean udders, and to milking

with wet hands, to the handling and prolonged exposure of the milk and cream in poorly ventilated stables, and to not removing the animal heat from the milk or cream promptly. Aside from the presence of impurities in milk and cream produced under these insanitary conditions, that themselves contain the cowy odors, the activity of the multitude of germ life associated with these impurities and related to the intestinal flora, such as strains of the Coli-aerogenes type, may be expected to contribute to this character of off-flavors.

The prevention of this flavor defect obviously calls for such sanitation and cleanliness in the production and handling of cream on the farm, as will guard against contamination with manure, stable dust, and impure stable air. It means clean udders and flanks, milking with clean, dry hands, prompt removal of milk from stable, and handling and storing of the milk and cream in a place free from stable air.

Unclean or Utensil Flavor.—As the name implies, this defect refers to butter that lacks the clean and delicately pleasant flavor and aroma. The off-flavor usually is not pronounced nor definite, but it is sufficient to bar the butter from a 92 score. The taste suggests contact of the cream with utensils incompletely washed, such as unclean strainers, cream cans, or separator bowls, or possibly faulty sanitary condition of factory equipment, such as vats, pumps, conveyors, pipes, churns, or packing equipment.

While the unclean flavor may be the direct result of contamination of the cream with milk remnants from unclean utensils, or of absorption of their odors, it may also be the indirect result of the activity of micro-organisms contained in the milk remnants of unclean utensils, and that thus infest the fresh cream.

Musty, Smothered Flavor.—When warm cream from the separator is held in a tightly sealed can, it often acquires a peculiar smothered, musty flavor and odor which may follow it into the butter. The storing of cream in a damp, musty-smelling cellar, or other poorly ventilated room, may cause a similar off-flavor in the butter. Empty, sealed cream cans that have been out of service for a considerable period are also capable of causing musty flavor and odor in cream and butter. In addition, musty flavor has been traced to the feeding of moldy hay,

moldy silage and musty grain. It is possible, too, for the butter to absorb a musty odor from wooden equipment or containers that give off such odors, such as churns and butter trucks that are in poor sanitary condition, musty ice boxes and refrigerators.

The obvious prevention of the musty, smothered odor of butter lies in prompt and proper cooling of the freshly separated cream, its storage in a properly ventilated place, aeration of returned empty cans while not in use and rinsing them out with clean water immediately before use, avoidance of feeding moldy, musty feed, the proper treatment of churns and butter trucks, and systematic inspection of the ice boxes and refrigerators in the stores handling the creamery's butter.

Malty Flavor.—This particular flavor in butter is characteristic of the flavor of malty cream. It is readily produced by a certain strain of lactic acid bacteria (Streptococcus lactis var. maltigenes). It is often contained in sweet or sour cream of high quality. The malty flavor in butter is criticized by some of the butter judges, but is generally accepted without complaint by the consumer.

Bitter Flavor.—Bitter flavor is found more frequently in milk and cream, but it is by no means foreign to butter. Bitterness in milk has been found due to such conditions as abnormal physical condition of certain individual cows, to certain feeds and weeds, and protein decompositon.

Some cows in late lactation regularly yield milk that has a bitter flavor. Such feeds and weeds as lupines, ragweed, bitterweed, beet tops (that have been allowed to freeze), rye pasture (in excess), raw potatoes, diverse decayed feed stuffs, moldy oat and barley straw, have been found to be the cause of bitter flavor. It is especially the bitterweed (Helenium teniufolium) of southern pastures and wastelands that contains compounds which are very bitter. McDonald and Glaser[5] showed that the bitter essence of bitterweed is crystalline, non-volatile, soluble in water, but insoluble in fat. The cream separated from the bitter milk usually contains enough bitter milk to taste decidedly bitter, and butter made from such cream by usual methods, likewise has a bitter flavor. These investigators recommend diluting the cream with skim milk or water, followed by reseparation, as a means to eliminate the appearance of bitter flavor in the butter.

The expense and fat losses associated with these reseparations are well known to those familiar with such practice.

Much of the bitter cream that arrives at the creamery is old, stale cream, in which the bitterness appears to be associated with protein decomposition. Some of this cream is intensely bitter. Weigmann[6] also discussed the possibility of the presence of bitter substances in such milk and suggests that the peptonizing of the milk proteins may yield bitter-tasting albumoses and peptones. He further states that certain species of the Coli-aerogenes group of bacteria, also Bact. Zopfi and Bact. lactis innocuum, are capable of making milk bitter. Experiments by Hunziker and Pitz[7] showed that old yeasty cream tends to have a bitter taste. These investigators found that the yeasts, classified by Hammer and Cordes[8] as Torula cremoris, first act on the lactose and are capable of completely using up the lactose content of the cream in 60 to 72 hours, at temperatures between 90° and 100° F. During this lactose fermentation, which yields chiefly carbon dioxide and alcohol, a pleasant aromatic "nutty" flavor develops. Upon continued action, however, the aromatic flavor disappears and gives way to a bitter flavor. Simultaneously with the appearance of the bitter flavor there is also a breaking down of the proteins yielding peptones, albumoses and amino acids. These results suggest that the bitter flavor here is due to the action of the yeasts on the proteins.

Jensen[9] reported S. casei amari as a cause of bitter milk. Harrison[10] discovered a lactose-fermenting yeast, which he gave the name Torula amara, that produced bitter flavor in milk and cheese in Canada. This organism produced intense bitter flavor in 14 hours. Spitzer and Epple[11] isolated an active proteolytic organism corresponding to Migula's classification of B. panis, that was capable of producing an intensely bitter taste in milk. They suggest that the excessive peptonizing function of this organism may be the primary cause of the bitterness. Conn, Burri, Düggeli, von Freudenreich and Gorini reported numerous peptonizing organisms capable of rendering milk bitter.

The extent to which the bitter flavor, developed in the milk and cream, reappears in the butter is variable. Butter made from old yeasty cream which has been treated with air to remove the volatilizable fermentation products invariably retains a disagreeable bitter flavor. Cream over-neutralized with lime also tends to yield butter that tastes bitter. The use of salt contain-

ing an abnormal quantity of such impurities as chlorides of potassium, calcium and magnesium, which impurities themselves have a strongly bitter taste, results in more or less bitterness.

Stale Flavor.—This flavor defect, if present in fresh butter, is characteristic of butter made from old, stale cream. Pasteurization, and more particularly steam treatment under vacuum, assist in minimizing this defect. The proper use of a good starter is often of additional help. In general, however, the stale character of the cream reappears in the butter.

Staleness of flavor is a common age defect of unsalted butter, especially that made from unripened cream. It develops in unsalted butter even when made from cream of good quality. It progresses rapidly at ordinary temperature, and somewhat more slowly at ice box temperature. In commercial cold storage, the staleness usually does not seriously develop until the butter is withdrawn from storage. The stale flavor in unsalted butter usually changes rapidly to a cheesy flavor (flavor of Roquefort cheese). The appearance of stale flavor in unsalted butter made from cream of good quality is materially retarded by the proper ripening of the cream, see Chapter XIV on "Cream Ripening."

Staleness and oxidized flavor are prone to develop also on the surface of butter, both salted and unsalted. This surface deterioration is due to the oxidizing action of the air. It is hastened and intensified in the presence of light. Its prevention lies in protecting the surface of the butter with a liner or wrapper that is air-tight and impervious to ultra-violet light. For details see Chapter XVII on "Packing of Butter."

Yeasty Flavor and Odor.—Yeasty flavor and odor in butter is a characteristic hot weather defect of butter. It is caused by the fermentation of the cream by certain species of yeasts. Butter that contains this off-flavor, even to a slight extent, is limited to a score of 89 points, and aggravated cases of yeastiness may drop the score as low as 87 points.

Two similar species of yeasts, capable of producing the yeasty flavor in butter, have been isolated from yeasty, foamy cream. Hammer and Cordes[8] assigned to them the names Torula cremoris and Torula sphaerica. In the early stages of the yeast fermentation of cream, the odor usually is of a not unpleasant, aromatic, nutty character. Prolonged yeasty fermentation such

as usually occurs in old, yeasty cream, generally gives the butter a disagreeable bitter yeasty taste.

In many cases the yeasty flavor and odor are accompanied by profuse foaming of the cream, due to vigorous formation of carbon dioxide gas. Under favorable temperature conditions the generation of gas is sufficient to cause the cream in the can to foam over and out of the can, involving loss of butter fat and causing unsightly and insanitary conditions.

Fig. 112. Yeasty, foamy cream

Hunziker and Pitz[7] examined 36 samples of commercial foamy cream, of which 16 were from Illinois, 2 from Indiana, 4 from Iowa, 2 from Kansas, 2 from Kentucky, 4 from Michigan, 4 from Missouri and 2 from Ohio. In each case the organism responsible for the foamy cream fermentation was found to be a sporeless yeast, or torula, of the same microscopic, cultural and biochemic properties as, and otherwise closely resembling, Torula cremoris.

This yeast produced large quantities of carbon dioxide gas, some alcohol and under favorable temperature conditions used up completely all the lactose present in the cream in from 72 to 160 hours. The acidity of the cream increased somewhat up to a certain stage and later decreased slightly. Titration (after boiling) showed a maximum acidity of about .45% to .5% calculated as lactic acid.

The foamy-cream yeast grew equally as well in sour as in sweet cream and it developed gas in cream and in wort containing as high as 3.0% lactic acid. Gas production was most rapid at incubating temperatures between 90° and 95° F. At 110° F. gas production ceased. The lowest temperature at which gas formed was 68° F. after 6 days of incubation. At temperatures between 85° F. and 105° F. gas production commenced within 24 hours of inoculation. The thermal death point was found to lie between 55° and 58° C. (131° and 136.4° F.), with an ex-

posure of 10 minutes, varying somewhat with the virulence of the culture.

Determination of the fat constants and protein properties of cream indicated that this yeast does not have any action on the butter fat, determinable by standard chemical methods, but that it does increase the amino nitrogen and slightly increases the percent soluble protein, when the fermentation is allowed to continue after the lactose content of the cream has disappeared. It is probable, therefore, that the disagreeable bitter yeasty flavor of butter made from old yeasty cream is due to protein decomposition products resulting from advanced yeast fermentation.

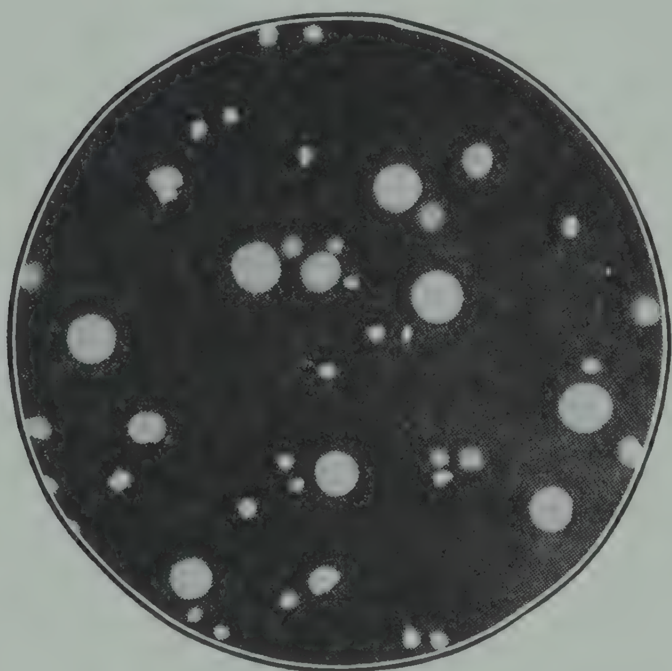


Fig. 113. Yeast colonies on lactose agar

Fig. 114. Yeast cells
(Magnified X 510)

The distribution of lactose-fermenting yeasts that are capable of causing yeasty flavor in butter, is wide-spread. Some cells of these yeasts may be found in most samples of cream, particularly during summer. Under normally proper conditions of production and handling of cream, relative to cleanliness of utensils, prompt and proper cooling, and frequency of delivery, they appear to do no harm. The defect of yeasty flavor in butter and foamy cream is confined largely to sections of the country where dairying is a side line, the dairy cows per farm are few, facilities and efforts for proper care on the farm are limited and deliveries are infrequent. It is especially prevalent at times when both the days and the nights are hot and the cream is held for several days, or longer, without adequate

cooling. Even when partially cooled the cream may start foaming, if held long enough.

The findings of Hunziker and Pitz, which involved the inspection of the farms of 161 creamery patrons, showed that the great majority of cans of yeasty cream come from farms where the cream separator is not washed after each separation. In general, these same farms also lacked facilities for cream cooling, and intervals between deliveries were unduly long.

Prevention of Yeasty Flavor and Foamy Cream.—The following precautions are recommended:

1. Wash and scald all milk utensils, such as strainers, pails, dippers, cans, etc., after each use.

2. Wash and scald all parts of the cream separator that come in contact with milk and cream, after each use.

3. Cool the cream as soon as it leaves the separator to as low a temperature as possible, preferably below 60° F.

4. Use a cream cooling tank and keep the cream in cold water until it leaves the farm.

5. Protect the cream cans in transit from summer heat by covering them with wet blankets.

6. Do not allow the cans to stand on the station platform exposed to the sun in hot weather.

7. Deliver or ship the cream often, at least every other day, or oftener in summer.

8. Handle the cream promptly and properly upon arrival at cream station or creamery.

Cheesy Flavor.—Butter with a cheesy flavor, due to the condition of the cream, is of poor quality, seldom scoring above 88 points. It denotes a very low grade of raw material. The cheesy flavor in such case is usually of the Cheddar cheese character. It is the result of very old cream that has been produced and held under conditions that cause high acidity, curdiness and curd decomposition. Such cream may also show mold growth. It is a type of cream that should be rejected by the creamery. The prevention of cheesy flavor in butter at the churn is wholly a problem of eliminating old cheesy cream from manufacture.

The development of cheesiness in cream is readily avoided by ordinary attention to cleanliness and care on the farm and

to reasonably prompt delivery. The cheesy flavor of cream does not respond to flavor-removing treatment in manufacture. The presence of cheesy flavor in butter at the churn should not be confused with cheesy flavor that may develop in butter after manufacture, due to bacterial contamination, for the discussion of which see "3.) Flavor Defects that May Develop After Manufacture."

Metallic Flavor.—By metallic flavor in butter is generally understood a flavor that resembles the astringent, puckery taste that is characteristic of the taste of metallic salts formed by such metals as iron, copper, zinc, etc., in acid solutions. This flavor defect is not always sharply defined, the suggestion of metallic flavor is in some instances associated with other flavors in butter, such as oily flavor, fishy flavor, tallowy flavor.

The typical astringent and puckery metallic flavor in butter is usually present at the churn and is not known to develop in butter storage. Its cause is not always satisfactorily established. Both experimental evidence and commercial experience indicate that it may be produced by more than one cause. Its occurrence has been traced to contamination of the cream with metallic salts, as well as to the action of certain species of bacteria.

Metallic Flavor Due to Absorption of Salts of Metals.—The absorption of metallic salts by the cream before it reaches the creamery is probably the most common cause of metallic flavor in butter made from sour farm-skimmed cream. This is attributable chiefly to the condition of the utensils in which the cream is held on the farm and of the cream shipping cans.

The generally prolonged holding of the farm-skimmed cream in the usual tinned steel pails, or cans, causes more or less rusting of the base metal, contaminating the cream with iron oxide. This action is intensified by the souring of the cream. In an extensive study of the cause of metallic cream received at a creamery, by Hunziker and Cordes,[12] farm inspection showed that on one farm that persistently supplied intensely metallic cream, the bottom of the shot gun cans in which the cream was held had rusted through and had to be plugged with rags to prevent loss of cream. In the same investigation the tasting of the cream nearest the wall of the cream shipping cans demonstrated that the cream in contact with the side of the can was invariably definitely metallic in flavor, while the

cream taken from the center of the same cans before stirring was free from this flavor. Cream in contact with the metal in aluminum cans, on the other hand, was free from metallic taint.

The metallic flavor increased with the acidity of the cream and it was especially noticeable in the case of the richest cream. The butter made from metallic cream was metallic at the churn. The metallic flavor in the butter is usually intensified by pasteurizing such sour cream without neutralization, or by the use of high pasteurizing temperature (185° F. flash), by liberal dilution of rich cream with water and by high acidity of the cream at churning time.

Metallic flavor in butter may also result from exposure of cream or butter to surfaces of damaging metals in the equipment used in manufacture. Exposed surfaces of copper, such as in copper vats, forewarmers, pasteurizers, cream pipes, etc., with defective tin coating; also surfaces of alloys containing considerable copper, such as white metals, are potential sources of metallic flavor in butter. The danger here is augmented by an unclean, oxidized, tarnished, or corroded condition and by exposure to such metal surfaces in the presence of heat, air and light. Likewise, contact of the butter with damaging metals in the churn, or in packing equipment, may give the butter a metallic flavor. Butter sticking to iron bolt heads, or to galvanized iron caps of the worker rolls in the churn, turns metallic even during its short contact while unloading the churn.

In general, however, the appearance of metallic flavor in butter has to do more directly with rusty containers of cream, than with the metallic surfaces in plants equipment.

Metallic Flavor Due to Bacterial Activity.—Metallic flavor may appear in cream and butter in the complete absence of metal surfaces and metallic salts. Guthrie[13] and Cordes[14] produced metallic flavor in milk and in cream in glass containers, by the use of bacterial cultures. Both investigators demonstrated independently, that starters at certain advanced stages of fermentation, may and often do become metallic and may cause metallic flavor in the cream inoculated with them. High acidity is practically always a factor in the combination of conditions that produces this flavor defect. Cream rich in butter fat, likewise, is more susceptible to the tendency to develop metallic flavor than cream low in butter fat.

Prevention of Metallic Flavor.—The results of experimental investigation and commercial experience suggest the following precautions to prevent the appearance of metallic flavor in butter:

1. Avoid receipts of metallic cream by acquainting the producers with the dangers of rusty containers and by emphasizing the importance of sanitary care, efficient cooling and frequent delivery, and by returning to them empty cans that are clean, thoroughly steamed, dry, and free from rust. Efficient cream grading and equitable quality-paying are the most effective means of assuring the farmer's co-operation.

2. Encourage the production of cream of moderate richness, preferably containing not over 35% fat.

3. Keep all copper surfaces in plant equipment properly tinned. Avoid copper alloys, such as white metal for vat linings and coils, etc. This precaution is especially important in connection with the surface cooler. Running the hot cream in a thin layer over a defective surface cooler provides a combination of conditions—oxidizing metal, heat, light, air—that is highly conducive to metallic flavor in butter.

4. Keep metal surfaces in plant equipment bright and shining, and flush with hot water each morning before the cream is permitted to circulate.

5. In the case of sour cream, reduce the acid before pasteurization (preferably to 0.25% or lower), and hold the churning acidity down similarly.

6. Do not over-ripen the starter and do not hold it excessively long.

7. When receiving cream with metallic flavor, avoid high temperature pasteurization. See also "Oily-Metallic Flavor" later.

Kerosene and Gasoline Flavor.—Butter tainted with these flavors is officially scored "No Grade," and generally has to be disposed of as packing stock. These flavor defects are usually associated with conditions that cause absorption of their odors by the cream, and in some cases by accidental contamination of the cream with small amounts of the products themselves.

Common causes of such absorption or contamination are the temporary use of cream cans as containers for transporting these products from filling station or country store to farm, or per-

mitting the gasoline engine that may drive the cream separator to exhaust into the milk room.

Cream cans should not be used for such purposes. Cans that have contained kerosene or gasoline are difficult to clean in a manner that removes all traces of their odors. The most dependable means of prevention of kerosene and gasoline flavor in butter lies in careful cream grading, and rejection of cream that is impregnated with them.

2. FLAVOR DEFECTS OF FRESH BUTTER DUE TO FAULTY METHODS IN MANUFACTURE

Flat Flavor.—Butter termed flat in flavor lacks the pronounced, pleasing flavor and aroma that is characteristic of butter of really superior quality. Such butter lacks character. Its quality is negative. If only slightly flat, such as is often the case with butter made from good cream that is churned sweet, such butter may receive a score of 92. If definitely flat, but otherwise of clean flavor, it will score 91.

The fundamental cause of this flat flavor character lies in low content of volatile acidity, diacetyl and other products that make up the desired complex of desirable butter flavor. The chief conditions responsible for deficiency in butter flavor compounds are: cream from stripper cows, churning the cream sweet and without the use of starter, profuse dilution of the cream with water, and excessive washing of the butter. The flat character resulting from any one or all of these conditions is accentuated in the case of unsalted butter.

The flat and washed-out character of butter is avoided by the use of a good starter, as explained in Chapters XIII and XIV, on "Starters" and on "Cream Ripening," respectively, by so organizing the rinsing of cream cans, forewarmers, pasteurizers, vats, and other equipment from which remnants of cream are reclaimed, as to avoid undue dilution of the cream, and by not washing the butter more than is necessary to prevent a milky tear.

In the case of some churnings of butter, a flat, dead flavor of the fresh butter is the characteristic forerunner of staleness, followed by cheesy or putrid flavor. Its lifeless character suggests the beginning of flavor deterioration. In such case, bacteriological examination usually indicates copious contamination

with flavor-damaging rods, and the incubation test shows poor keeping quality.

High Acid and Sour Flavor.—High acid flavor in butter is characteristic of butter made from cream received in sour condition and that is not neutralized before pasteurization. It was a common hot weather defect of butter made from sour, farm-skimmed cream in the days prior to the advent and general practice of neutralization of sour cream. The high acid flavor of this origin is readily avoided by proper neutralization.

High acid flavor and aroma may also be caused by churning over-ripened cream, or by the use of over-ripe starter, or by attempts at producing high flavor and aroma by the use of high cream ripening temperatures in the presence of a starter that lacks flavor organisms and produces acid only. The use of a starter containing the proper balance of acid and flavor organisms, together with intelligent co-ordination of the temperature and time of cream ripening, eliminates the danger of excessively high acid flavor and aroma in butter made from ripened cream.

Butter with a typical sour flavor is usually the result of the presence of excessive buttermilk. Such butter may also develop a curdy, cheesy flavor. It usually lacks keeping quality. This defect is obviously due to insufficient washing and is readily avoided by washing the butter sufficiently to avoid a "milky tear" on the butter.

Coarse Flavor.—Similarly as unclean flavor, the coarse flavor represents a taste sensation difficult of definite description. It has to do with an impression of absence of the pleasing delicate flavor that is characteristic of good butter. It is usually associated with excessive saltiness, such as occurs in full salt butter with rather loosely incorporated brine. The coarseness may be intensified in the case of high acid or over-ripened cream. Well-worked butter of moderate salt content, made from cream with a low churning acidity, is usually not subject to this criticism.

Cooked or Scorched Flavor.—The cooked flavor is characteristic of butter made from pasteurized cream. It is caused by exposure of the cream to high temperatures. Most butter made from pasteurized cream has a slight cooked flavor when fresh. This flavor is not objectionable and it usually disappears before the butter reaches the market. In the case of the hold-

ing process of pasteurization at 145 to 150° F. for 30 minutes, the cooked flavor is negligible. At high temperature flash pasteurization, such as 185 to 200° F., there is a tendency toward a slight increase in cooked flavor. Prolonged periods of holding (30 minutes or longer) at relatively high temperatures (above 165° F.) are most conducive to the appearance of a noticeable cooked flavor.

Under certain conditions of operation the cooked flavor of butter becomes sufficiently pronounced to be termed scorched. This occurs when crowding the heating surface of the pasteurizer to excessively high temperatures, causing overheating and scorching of the cream that comes in direct contact with it. The damage in such case is aggravated when the heating surface is not fully covered by the cream, causing a thin film of cream to burn on. The ideal manner of pasteurization for avoiding cooked or scorched flavor, is that of maintaining the heating medium and the heating surface at a temperature only a few degrees above the desired pasteurizing temperature of the cream.

The character of the cream itself is a factor in determining the intensity of cooked flavor produced. Sweet cream is the least sensitive to the temperature of pasteurization. Sour, farm-skimmed cream, though neutralized before pasteurization, does not withstand as high pasteurizing temperatures without danger of scorched flavor in the resulting butter, as does sweet cream.

Pasteurization of such cream at temperatures above 160° F. and holding for 20 minutes, tends to yield a scorched flavor in the butter. At 160° F. or below, the danger of cooked flavor is much reduced, but even only a few degrees above 160° F. greatly augments the tendency for an objectionable scorched flavor. This defect may drop the official score to 89 in the case of an otherwise 90 point butter.

Heating the cream by means of direct steam pasteurization under pressure (with "live steam"), and without metallic heating surface, minimizes the danger of cooked or scorched flavor, even when pasteurizing at high temperatures (above 200° F.).

Neutralizer Flavor.—Neutralizer flavor is occasionally found in butter made from neutralized sour cream. The tendency for this defect to appear, and its intensity, depend largely on the amount of neutralizer used, as determined by the degree of original acidity present and the point neutralized to, as well

as on the care exercised in the operation of the process. The sourer the cream and the lower the point to which it is neutralized, the greater is the tendency for butter to show neutralizer flavor, especially in the case of careless operation.

The exact character of neutralizer flavor depends on the type of neutralizer used, whether lime and magnesia neutralizer, or soda neutralizer. With the former the neutralizer flavor, if any, is of a limy, bitter nature; with the latter, the tendency lies in the direction of a soapy flavor. In either case, the most common causes of neutralizer flavor are:

1. Neutralizing to too near the neutral point, especially in the case of high-acid cream.

2. Adding the neutralizer in too concentrated form, not distributing it quickly and uniformly throughout the body of the cream, or not giving the neutralizer sufficient time to complete the reaction in the cream, before starting to pasteurize.

When neutralization is properly done, there is very little danger of imparting to butter a neutralizer flavor. See also Chapter X on "Neutralization of Sour Cream."

Oily or Oily-Metallic Flavor.—This flavor defect of butter rarely, if ever, appears in butter made from cream of good quality, sweet or only slightly sour. It is typical, however, of some of the summer butter made from sour, farm-skimmed cream, such as is received by the majority of creameries in the corn belt states of the Middlewest. When it occurs, this defect is usually present in the fresh butter at the churn. There is no evidence that it develops in butter after manufacture. The oily-metallic flavor defect limits the score of butter to 89 points.

The exact reactions responsible for this defect are not as yet fully understood. Observations to date, however, suggest that direct action by bacteria is not involved. Its general character, and the known conditions incident to its development, point in the direction of reactions leading to oxidation of the butter fat, as the direct cause. These reactions may, and probably do have something to do with the presence of decomposition products resulting from bacterial action in the original cream, and which are contained in the cream at the time of its arrival at the creamery. Whether the presence of metallic salts is a factor in the reactions is not definitely known.

Observations over a protracted period of years by Hunzi-

ker[15] have provided unmistakable evidence that certain combinations of factors and conditions in manufacture produce the defect with fairly dependable regularity. The same investigator and co-workers, have likewise demonstrated that certain modifications or control of these factors, make possible the prevention of the defect. The more important of these factors are:

1. High-acid cream.
2. High fat content cream.
3. High temperature of pasteurization.
4. Prolonged holding after pasteurization and cooling.
5. Contamination of the cream with metallic salts.

HIGH ACID CREAM. Sour cream of mediocre quality appears to be the fundamental cause. Sweet cream of good quality does not produce the defect.

HIGH FAT CONTENT OF CREAM. Cream rich in fat (well over 33% fat) develops the oily-metallic flavor in butter far more readily than cream with low fat content.

HIGH TEMPERATURE OF PASTEURIZATION. Experiments with split churnings, as well as observations in the commercial manufacture of hundreds of churnings of butter, have conclusively shown that high temperature flash pasteurization (185° F.), with or without vacuum treatment, of sour neutralized cream, especially cream rich in fat, provides a combination of conditions that is highly favorable to the production of oily-metallic flavor in the butter.

Observations in factory operation covering a wide range of seasonal and local conditions suggest that pasteurizing temperatures within the approximate limits of 170 to 190° F. represent a temperature range that is particularly critical and especially conducive to the reactions responsible for oily-metallic flavor in butter made from the type of cream that is susceptible to such reactions. With vat pasteurization at 145 to 160° F. for 30 minutes, this flavor defect does not develop. Likewise, at temperatures above the boiling point reaching into the range of 230 to 250° F. the defect appears to be decidedly less pronounced.

PROLONGED HOLDING AFTER PASTEURIZATION and COOLING. Prolonged holding after cooling, of the cream that was pasteurized within the temperature range that causes oily-metallic flavor, accelerates the defect. If this cream, flash pasteurized at say

180 to 185° F., is held for a number of hours after cooling, such as six hours, or over night, and is churned the following morning, the resulting butter is almost sure to show the oily-metallic flavor. If churned promptly after cooling (such as within about an hour), the defect is appreciably minimized and may in most cases be prevented.

CONTAMINATION OF THE CREAM WITH METALLIC SALTS. To what extent, if any, the presence of metallic compounds in the cream enters into, or is responsible for, the reactions that produce the oily-metallic flavor, has not been conclusively determined. Cream produced under conditions that cause this flavor defect in butter may be expected to harbor iron oxide or salts derived from rusty utensils and shipping cans. Traces of copper salts from exposed copper surfaces in plant equipment are likewise probable. However, available data also show that the handling of cream in glass-enameled equipment, and in laboratory experiments in which glass containers only were used, to the exclusion of all metal surfaces, failed to prevent oily-metallic flavor when other conditions were favorable to produce the defect.

Notwithstanding these apparent contradictions of available evidence, the fact remains that iron oxide and copper salts are active oxidizers and catalizers that may be expected to intensify, if not incite, reactions leading to the appearance of the oily-metallic flavor defect. Consideration of means for its prevention, therefore, cannot consistently ignore the metallic condition of cream containers used on the farm and for transportation, and of factory equipment, as a potential menace, and must embrace, as far as possible, the elimination of contact of cream with bare iron and copper surfaces.

Prevention of Oily-Metallic Flavor.—As pointed out in earlier paragraphs, cream high in acidity and otherwise of mediocre quality, is the fundamental cause of this defect. Cream of good quality, sweet or only slightly sour, is the most dependable preventative. Observations and experiences in manufacture suggest the following procedures with cream that is prone to produce oily-metallic flavor:

1. Vat pasteurization at temperatures not exceeding 160° F., preferably at 145 to 160° F. for thirty minutes.

2. If higher pasteurizing temperatures must be used, churn as soon as possible, preferably within one hour or less after cooling the pasteurized cream.

3. Avoid contact of the cream during manufacture with bare surfaces of iron or copper, and eliminate rusty cream shipping cans.

3. FLAVOR DEFECTS THAT MAY DEVELOP AFTER MANUFACTURE

Surface Taint, Limburger, or Putrid Flavor.—The designation—Surface Taint—refers to butter that has a putrid flavor and odor. This designation appears to have originated in Canada and was later also adopted in the United States. The defect was called surface taint, because it appeared first, or was noticed first, on the surface of butter. However, the putrid flavor is by no means confined to the surface, it rapidly involves the whole mass or package of butter. The term "surface taint" appears an unfortunate designation, not only because it conveys no tangible meaning as to character of flavor defect, but it is confusing in that it suggests surface flavor or surface deterioration which is usually understood to be associated with surface oxidation or "toppiness," resulting from incomplete protection of the surface of the butter against air.

The putrid flavor defect is also occasionally designated as Limburger flavor, suggesting the flavor and odor of Limburger cheese. While there is some resemblance of general flavor character, the typical surface taint flavor is much more objectionable, being distinctly of the putrid and foetid type.

This defect is undeniably the most disgusting of all off-flavors of butter from the consumer's viewpoint, and the most ruinous from the sales standpoint of the creamery. Epidemics of surface taint, unless promptly checked, spell disaster to the creamery business.

Butter may show the putrid flavor defect in a very few days after manufacture. It is capable of development at the usual temperatures of the creamery cooler (40 to 55° F.). At room temperature and higher, development is most rapid. It does not develop in butter held in commercial cold storage, nor after such storage.

The appearance of putrid flavor in butter is retarded and to a large extent entirely prevented in the case of butter made from ripened cream, and of butter with a high salt content (3% salt or over). Light-salt butter and butter made from sweet or unripened cream, on the other hand, are very susceptible to this

flavor defect, provided that the causative agencies are present. This applies to all butter, regardless of quality of original cream.

It is chiefly for these reasons that putrid flavor has been and to some extent still is a serious menace to the butter from countries that churn their cream sweet or unripened, and whose markets demand a very light-salt butter, such as is the case with the great butter producing Dominions of the British Empire—Canada, Australia, and New Zealand. On the Continent of Europe, the consumer demands butter with high flavor and aroma, such as requires ripening of the cream to a relatively high acidity. This fact explains, in a general way, why the butter industry in Continental Europe has been enjoying comparative freedom from the defect of putrid flavor in their butter.

Because of the complete absence of salt, unsalted butter made from sweet, unripened cream is highly susceptible to surface taint. When made from cream properly ripened, unsalted butter does not develop this defect.

In the United States putrid flavor in salted butter has become a problem only within the last ten to fifteen years, largely because our markets in prior years tolerated a relatively high salt content (about 3% salt), which kept the putrid flavor defect in check. The increasingly growing general demand in more recent years, for a lighter salt butter, has caused the lowering of the salt content of American butter to an average of approximately 2%. This change to a milder salt butter has augmented the potential menace of surface taint to a point that compels serious attention to methods and means for its prevention.

The causes of surface taint have been studied by Gilruth[16], Orla-Jensen[17], Sadler and Wollum[18], Hunziker and Cordes[19], Hood and White [20], Macy[21], Shutt[22], Brown[23], Derby and Hammer[24] and many other investigators. The general observations made and conclusions drawn from these investigations, involving work done in many different countries, are in remarkably close agreement to the effect that:

1. The putrid defect is the result of protein decomposition brought about by the presence in butter of certain species of putrefactive bacteria.

2. While the total bacterial and yeast count of surface taint butter is usually abnormally high, the number of organisms of the species that are responsible for the defect and which, when inoculated into new pasteurized cream will reproduce the defect,

is generally small. Not infrequently they are not found at all. Furthermore, attempts at reproducing the defect by inoculating fresh butter with surface taint butter have consistently failed. Normal butter inoculated with surface taint butter does not develop surface taint.

The persistence with which bacteriological analysis of surface taint butter reveals the presence of surprisingly small numbers of the causative organisms, if any; and the inability of reproducing the defect in sound butter by inoculation with surface taint butter, while inoculation of cream with the defective butter does yield butter that develops the characteristic putrid flavor and odor, suggest that enzyme action may be involved. It is conceivable that the causative organisms produce enzymes that are active in decomposition changes leading to surface taint, and that their action continues after the decline of the causative organisms. This possibility is further supported by the assertion of Lea[25] that "Many organisms produce enzymes which decompose the proteins in fat-containing foods, with the production of substances of unpleasant taste and odor, such as indole, skatole, hydrogen sulphide, methylamines and ammonia, or breakdown proteins, carbohydrates and fats to propionic, butyric, lactic and other volatile fatty acids. Such organisms are responsible for surface taint in butter."

3. More than one species of bacteria has been found capable of producing surface taint in butter. To these species belong a rod shaped organism designated Achromobacter putrefaciens, named by Derby and Hammer[24], Pseudomonas fluorescens, and Bacillus fluorescens liquefaciens.

4. The putrid flavor defect in butter made from efficiently pasteurized cream is not due to the microflora or its products originally present in the cream, but to contamination of the cream or butter after pasteurization. The surface taint-producing agencies are not heat resistant. They do not survive the lower temperature limits of standard pasteurization (145° F. for 30 minutes, or 180° F. flash).

The ease with which unsalted or light-salt butter made from sweet or unripened cream, falls prey to surface taint, even that made in factories that maintain an apparently high standard of sanitation, suggests a wide range of distribution of the causative organisms. These organisms are known to be present in pol-

luted or stagnant water; the raw cream may also harbor them, and hidden remnants of milk products in equipment appear to constitute highly favorable breeding places. Prevention of the defect, therefore, calls for such vigilance as to provide exemplary sanitary efficiency of plant equipment, supplies and operation, supplemented by systematic checks on the quality of the butter by incubation tests on butter samples at regular and reasonably frequent intervals.

In the absence of specific contamination with the germs of putrefaction or their enzymes, the defect of putrid flavor is impossible. Its occurrence is dependable evidence of a definite source of contamination somewhere in the plant between pasteurizer and finished package of butter. Quite often the seat of the trouble is where least expected and so inconspicuous or seemingly hidden, that it escapes routine inspection. Its location, therefore, calls for the most painstaking inspection of every phase of plant condition and operation.

If the creamery is not aware of the defect in its butter until complaints and returns of surface taint butter arrive from the market, it may suffer heavy losses before the trouble is under control. Many defective churnings may already be out among the trade and many more may result because of the usual difficulty of locating the cause, and the time lost before successful prevention. This emphasizes the importance of regularly checking the butter for keeping quality by the use of the bottle test (incubation test). Freedom from objectionable odors after four to eight day incubation at room temperature (70° F. or higher), is a dependable indication of absence of plant conditions that are conducive to the defect of surface taint. Indication of signs of off-odor in any samples in the test, should be regarded as a sufficient warning that the butter is not immune to this defect, and should be followed by an immediate, searching check-up on the efficiency of every detail of plant sanitation. For details of bottle test see "Rapid Incubation Test," Chapter XXV.

In the interpretation of the incubation test it is important to bear in mind, that the presence of any objectionable odor indicates damaging contamination that may, and predominatingly does, lead to surface taint. Long experience with surface taint problems has conclusively demonstrated that the putrid odor may be preceded by other odors, such as cheesy or rancid, etc. In salted butter (2.5% salt or less), the tendency appears to be

for the rancid odor to appear first. In unsalted butter the putrid odor more often precedes rancidity. Thus, the particular off-odor noted in the bottle test may, in some cases, vary with the time of inspection and with temperature conditions. The situation is aptly expressed by Macy[26]: ". . . many of the defects in butter are apparently stages in the deterioration of butter. We have observed many times a sequence of changes not always the same. For instance, an experimental butter may be criticized originally for being fruity; a few days later cheesy; then subsequently surface taint or putrid and finally rancid."

Prevention of Surface Taint.—The precautions necessary for the successful prevention of surface taint inevitably deal with a succession of minute details. Their importance cannot be over-emphasized, no matter how trivial they may appear. Attention to the following items is recommended:

1. EFFICIENCY OF PASTEURIZATION. This means exposure to the full pasteurizing temperature of every part of the cream, including also the foam and the cream in the gate nipple, and maintenance of the full temperature during the entire holding period. In the absence of a sanitary flush valve, the nipple at the gate end of the vat should be as short as practicable. To insure absence of raw cream in nipple, draw off a pail full of cream at the vat gate as soon as the full vat temperature has been reached and pour it back into the vat. In flash pasteurization it means maintenance of a uniform temperature during the entire run and by-passing of all cream that is under-pasteurized.

2. SANITATION BETWEEN PASTEURIZER AND CHURN. Make sure that vat liner does not leak cream into the insulation, there are no cracks in the liner of the vat cover, the coil is not leaking, and that the packing in the glands and bearings of the coil shaft is in sanitary condition. Surface coolers and international tube coolers must be clean, and receive sterilizing treatment before circulation of cream. Cream pumps, pipes and conveyors must be independent of all pipes, fittings and pumps that service raw cream or buttermilk. Keep strainers used for the pasteurized cream, such as pipe strainers and churn strainers, off the floor when not in use, and steam them thoroughly before use.

3. CHURNS. Make sure that all wooden parts, including barrel, shelves, (sides and both ends) and the worker rolls (both ends), are free from decayed wood and are treated daily as rec-

ommended in Chapter IV, under "Treatment of Churns." In case of doubt as to sanitary condition, give churn barrel a salt mush treatment after the last rinse at night and a chlorine water rinse before use in the morning. See Chapter IV. Consider the churn one of the most potential sources of surface taint contamination.

4. BUTTERMILK. The arrangement of the disposition of buttermilk must be such that there is no possibility of the buttermilk contained in the line to the buttermilk tanks flowing back into the churn. The buttermilk pipe is seldom clean and it usually contains decaying milk remnants pregnant with putrefactive germ life. See Chapter IV.

WATER SUPPLY. Polluted water, and stagnant water from dead pipe ends and in water storage tanks, are natural breeding places of surface taint organisms. Many costly cases of surface taint in butter have been traced to the water. Have the water supply analyzed for organic matter and bacteria to determine its fitness for use. In case of uncertainty or suspicion as to its sanitary purity, pasteurize the water, or chlorinate it (using 25 ppm) before use. In case of chlorinating allow thirty minutes after adding the chlorine to insure full sterilizing action in the water. Eliminate all dead pipe ends from the water line, and empty and cleanse water storage tanks at regular and sufficiently short intervals to insure a sanitary condition of tank and absence of stagnant water.

These precautions apply to all water that comes in contact with cream or butter, i.e., the water used for rinsing the vat down at the time of filling the churn, the water used for washing the butter, and the water that is added to the salt and for moisture control. They should apply also to the cold rinse water used for the chilling of wooden equipment. Contamination of wooden churns and butter workers from repeated contact with polluted water is a serious menace. It encourages progressive impregnation of the wood with putrid flavor organisms that will contaminate the cream and butter during churning and working.

PRECAUTIONS IN PACKING BUTTER. The danger of damaging contamination in the packing of bulk butter is not great, because the butter tampers and trucks are readily kept clean and in sanitary condition. Nevertheless, they are possible sources and need frequent thorough inspection. In the case of print butter, the

danger of contamination leading to surface taint is ever present, and a great multitude of cases of putrid flavor in print butter made from churnings that were above reproach before entering the butter cutting machine and yielded negative bottle tests, has occurred.

In such cases of bulk butter that showed satisfactory keeping quality, while prints made from the same churning developed surface taint, the cause was invariably traced to the wooden hopper boxes and rolls of butter cutting machines with the Archimedean screw. The wooden hopper boxes of these machines, especially, are of such construction as to readily gather and hide remnants of butter in cracks and in imperfect joints between the wood parts. These remnants are not accessible to and are neither removed nor sterilized by the routine cleaning and sterilizing treatment. They, therefore, decay and become a most prolific source of contamination with putrid-flavor organisms, of the butter that passes through the machine. Their menace can be minimized by special treatment with steam and chemical disinfectants, but even such treatment, much as it adds to the operating cost, fails to satisfactorily remove the cause. The most dependable remedy in such case is to discard the wooden hopper boxes and replace them with boxes constructed of a suitable metal.

Cheddar and Roquefort Flavors.—It was pointed out earlier in this chapter that cheesy flavor, especially in salted butter, if present in the fresh butter at the churn, is primarily due to cheesy flavored cream, and that such cream is invariably of very poor quality, making a low grade of butter that rarely scores over 88 points. Unsalted butter, if made from such cream, would obviously also have the same flavor defect, but a better quality of cream is generally used for unsalted butter.

The present discussion has to do with cheesy flavor of either the Cheddar or the Roquefort cheese type, that develops in butter after manufacture. The prevention of these flavors is a real problem, particularly as related to unsalted butter and very light-salt butter. Heavily, and even moderately salted butter seldom develop these defects. In unsalted butter, these flavor defects develop rapidly at room temperature, and more slowly at ice box temperature (40 to 50° F.). The defect is absent in butter held in commercial cold storage.

The work of Herreid, Macy and Combs[27] suggests that the Cheddar cheese type of flavor is caused by associative action of several species of bacteria and that proteolysis is involved and possibly also fat hydrolysis. These observations are also supported by the studies of Hammer[28].

The Roquefort cheese flavor of unsalted or light-salted butter is usually associated with mold growth which involves both proteolysis and fat hydrolysis. Observations in the commercial manufacture and marketing of unsalted butter suggest that the Cheddar cheese and the Roquefort cheese flavor defects are age defects to which this type of butter, when held above the freezing point, will eventually succumb. Resistance of the butter to this type of flavor defect will inevitably and primarily depend on the standard of sanitation in manufacture. The better the quality of the cream, the greater the germ killing efficiency of pasteurization, and the more complete the exclusion of subsequent contamination, the longer will the butter retain its original fresh flavor and the more successful the retardation of the appearance of the cheesy flavor defect.

Thorough pasteurization and a high standard of sanitation throughout manufacture will hold the number of the causative germs down to the minimum, and thereby retard the defect. However, unless sterilized and kept in hermetically sealed cans, or held at temperatures low enough to permanently inhibit all germ growth, unsalted butter will inevitably suffer progressive flavor deterioration due to microbiological activity. The usual trend of flavor changes is that of first showing a flat flavor, that changes to a stale flavor, later the staleness yields to cheesiness of the Cheddar type, followed by Roquefort flavor and rancidity.

The resistance of unsalted butter to bacterial age deterioration and to the development of cheesy flavor is further materially improved by ripening the cream with a good starter to a pronounced butter culture character and a reasonably high churning acidity (preferably about 0.35 to 0.45% acid). It appears that the great predominance of starter bacteria and the products of cream ripening are more or less antagonistic to the microorganisms responsible for the cheesy flavor defect, and definitely assist in holding them in check and in delaying age deterioration that causes the objectionable cheesy flavor.

Rancid Flavor.—Rancidity is a common flavor defect of butter made from raw cream. It is a characteristic age defect

of much of the butter made on the farm. Butter made from properly pasteurized cream by up-to-date methods of manufacture rarely develops this defect.

Rancid flavor in butter resembles the pungent, rasping taste and odor of such volatile fatty acids as butyric, caproic and caprylic acids. It is preeminently caused by hydrolysis of the fat, which splits the butter fat into free fatty acids and glycerol.

Rancid flavor resulting from hydrolysis of fat is brought about by the action of micro-organisms, or enzymes, or both. The early work of Orla-Jensen[29] and of Kirchner[30] demonstrated that certain species of micro-organisms, very commonly present in butter, are capable of hydrolizing the fat in butter to a marked degree and of producing an intense rancid flavor and odor. Some of the better known of these micro-organisms are Oidium lactis, Cladosporium butyri, Bacillus prodigiosus, likewise lipolytic strains of Pseudomonas and of Achromobacter, as shown by Hammer and Collins.[32] Lewkowitsch[33] suggests the possibility that even in the case of rancidity, apparently produced by these micro-organisms, the hydrolysis may be due to enzymes produced by them, rather than by their direct action on the fat. See also Chapter XXI under "Decomposition of Butterfat."

Prevention of Rancid Flavor.—Rancidity in butter is readily prevented by proper pasteurization of the cream, and efficient sanitation in plant management.

Of the equipment, the wooden churn and butter worker and the wooden butter cutter are the most common sources of contamination that lead to rancid flavor in butter. Freedom from decaying wood, and proper daily cleansing and sterilizing treatment are effective means of prevention. Polluted or stagnant water is prone to harbor the germs of rancidity. Observe same precautions on water supply as listed under "Prevention of Surface Taint."

Tallowy Flavor.—The tallowy flavor of butter resembles the flavor and odor of mutton tallow. In severe cases of tallowiness, the butter usually also bleaches in color. During the early days of cream neutralization, when over-neutralization often occurred, and when little attention was paid to the prevention of copper contamination from plant equipment, tallowy flavor in butter was a real menace. Due to the improvement in factory

equipment and methods of manufacture, the defect that involves the entire mass of butter, causing an intense tallowy flavor and bleaching, has been practically completely eliminated. Today, off-flavors in butter suggestive of tallowy flavor, are confined principally to surface deterioration of butter with age, the butter developing a tallowy or related flavor on the surface, in the absence of complete protection from air and light.

Similarly as rancid flavor, tallowy flavor is due to fat decomposition. However, while rancidity has to do with fat hydrolysis initiated by the action of lipolytic bacteria and enzymes, tallowiness is caused by oxidation of the fat, involving the unsaturated fatty acids in butter, such as the oleic acid. It was demonstrated by the early study of tallowiness in butter by Hunziker and Hosman[34], however, that butter does not show a tallowy flavor when oleic acid which has been exposed to the air until there has been a reduction in the iodine number, is added to it, but that butter containing free oleic acid becomes tallowy rapidly when exposed. These investigators concluded that tallowiness is the result of fat oxidation, but that the product which it is necessary to link up with the fatty acids, in order to make butter tallowy, is derived from free glycerol produced by a slight hydrolysis of the fat. They found this product to be glycollic acid ester of oleic acid. Only very small amounts (.25%) of this reagent added to butter fat produced a distinct tallowy flavor and odor. They point out further that glycollic acid is naturally found in the fat of sheep's wool, suggesting the probable close relation between glycollic acid and tallowy odor. See also Chapter XXI under "Decomposition of Butter Fat."

Causes and Prevention of Tallowy Flavor in Butter.—AIR, LIGHT AND HEAT.—Exposure to air is the most common cause of oxidation producing tallowiness in butter. Prolonged storage of butter without protection against the atmosphere causes surface oxidation associated with tallowy flavor on the surface of the butter. Such oxidation is greatly accelerated in the presence of heat and light. The development of tallowiness proceeds more rapidly in unprotected butter held at room temperature and higher, than at ice box temperature. At the temperature of commercial cold storage, butter does not become tallowy. Daylight, and especially direct sunlight greatly hasten fat oxidation and the development of tallowy flavor, accompanied by bleaching.

The use of air- and light-proof liners and wrappers, such as "parchfoil," or transparent wrappers, stained green or red, greatly retards surface oxidation and assists in minimizing, if not preventing surface tallowiness. Treatment of the wrapper with a harmless anti-oxidant, such as oat flour solution (Avenex) has also been found helpful in retarding surface oxidation of butter.

METALS. The presence in butter of certain metals, their salts or oxides, greatly hastens reactions that lead to tallowy flavor. Of the metals commonly used in dairy equipment and for cream containers, copper and iron are the most damaging. Other metals used in creamery equipment, such as tin, aluminum, stainless steel, chrome-nickel, and nickel, while not completely inert, have been found incapable of producing tallowy flavor in butter. In order, therefore, to eliminate metallic contact or contamination as a source of tallowy flavor in butter, iron surfaces, such as in cream cans, should be kept properly tinned and rusty iron cans should be eliminated. Copper surfaces in plant equipment should be kept properly tinned. The growing use of stainless steel equipment in the creamery within recent years has done much to eliminate occurrences of tallowy flavor in butter.

NEUTRALIZATION. The presence of an unnatural alkaline condition in cream or butter accelerates oxidation by promoting fat hydrolysis and resulting in accelerated oxidation, by making the resulting compounds (free fatty acids and glycerol) more susceptible to oxidation. Over-neutralization of cream aggravates the tendency of tallowy flavor in the resulting butter.

DIACETYL. It was shown by the work of King[35] that diacetyl is capable of causing tallowy flavor and bleaching of butter fat in the presence of air. In this experiment the amount of diacetyl added to the fat was 50 p.p.m. or more. This emphasizes the danger of fortifying the flavor of butter with excessive amounts of diacetyl compounds. When producing butter flavor naturally, i.e., by ripening cream with a starter containing lactic and aroma streptococci, the diacetyl content of the resulting butter usually falls within the range of 2.5 to 4.0 p.p.m. Experience in commercial butter manufacture has conclusively demonstrated that a diacetyl content of 4 p.p.m. does not produce tallowiness in storage butter, regardless of whether the diacetyl is produced by the starter in the cream, or added to the butter in the form of a synthetic diacetyl compound.

ABSENCE OF BACTERIA. The metabolism of bacteria and yeasts in dairy products appears to have some relation to the development of tallowy flavor. Tracy and Ramsey[36] found that the growth of bacteria in milk and cream contaminated with copper salts, retarded the development of tallowy flavor. They concluded that the effect is probably that of oxygen removal as the result of oxygen utilization incident to the metabolism of germ life. They further point out that lack of bacterial metabolism in the surplus sweet cream from milk plants and ice cream factories during the winter months, is probably the reason this cream, when churned, often produces a butter with a tallowy flavor.

Storage Flavor.—Butter that is held for a considerable number of months in commercial cold storage gradually surrenders some of its delicate flavor and aroma characteristic of fresh butter of good quality, and shows a peculiar age flavor known to the butter man as storage flavor.

In butter properly made from fresh, sweet cream of good quality, this change takes place very slowly and is usually barely perceptible after several months of cold storage. Rogers[37] reported that, in examining some millions of pounds of butter packed and stored for the U. S. Navy Department, sweet cream butter, almost without exception, kept through several months cold storage with only slight changes in flavor. These observations are fully supported by experience in commercial manufacture and storage of butter in general.

Butter that is made from sour, farm-skimmed cream of mediocre quality, on the other hand, develops the storage flavor more rapidly and more intensely, even when made from cream neutralized to the low acidity of sweet cream. As shown by Dyer[38], the characteristic storage flavor in such butter held in cold storage is due to slow but progressive oxidation of one or more of the non-fat constituents of buttermilk. It appears that neither neutralization, nor pasteurization completely eliminate the defects associated with promiscuous fermentation and high acidity in the cream before manufacture; the products formed in such cream, as the result of bacterial and enzymotic action and possibly also due to chemical changes, involving hydrolysis, or oxidation, or both, are beyond recall or correction by neutralization and heat treatment alone.

While efficient pasteurization and protection against recontamination after pasteurization will eliminate the danger of age deterioration due to bacterial causes, and while correct neutralization to the proper churning acidity will protect butter made from this mediocre cream against the tendency to develop fishy flavor, yet such butter is destined to develop the objectionable storage flavor. Even the low temperature of commercial cold storage is incapable of arresting the causative changes. In fact, the storage flavor becomes increasingly intense as cold storage is prolonged. Storage flavor is an age defect of butter held in cold storage, that appears to be preventable only by improvement of the quality of the cream supply.

Fishy Flavor.—Butter with this flavor defect has the flavor and odor characteristic of fish. Fishy flavor is a very serious defect of butter. Fishy butter is objected to by the consumer and shunned by the butter dealer. Butter only slightly fishy is limited to a score of 87. When pronouncedly fishy, butter is rated "No score." Fishy flavor is a flavor defect characteristic of cold storage butter produced under certain conditions, even when such butter is of apparently good quality at the time it enters cold storage. The defect is not confined to butter held in cold storage, however. It may also appear in fresh butter and in butter within a few days after manufacture.

Information supplied by the dairy research literature indicates that fishiness in butter has been traced to a variety of causes, ranging from the condition of the cow, character of her feed and water, activity of certain micro-organisms in milk and cream, method of manufacture, to absorption by the butter of the fishy odor from air impregnated by other products containing it.

Feeds Causing Fishy Flavor in Butter.—Harding, Rogers and Smith[39] investigated the cause of fishy flavor and odor in milk brought to the New York State Experiment Station by a milk dealer. The fishy taint was so pronounced that the milk was of no commercial value, although coming from a dairyman of more than ordinary carefulness in the handling of his herd. They found that the defect was confined to the milk of one cow that was fed on the same feed and received the same care as the other animals in the herd. This cow was apparently in normal

condition. Bacteriological study of her milk revealed no micro-organisms capable of producing the fishy flavor.

Weigmann[6] also reports a case where an individual cow which received the same feed and care as the rest of the herd, persistently produced a fishy milk. The fishy flavor of her milk was so marked that when mixed with the milk of the remainder of the herd, the mixed milk also became intensely fishy in flavor. In another case a cow produced milk with a fishy flavor only during the hot summer weather. This investigator further states that in Schleswig-Holstein, Germany, the opinion prevails that cows yield fishy milk when they pasture in the marshes which are periodically flooded by the tide and on the grasses of which small crabs and other sea fauna dry and decay. Sommerfeld[41] held that the fishy flavor was due to trimethylamine and that it resulted from cows grazing on meadows which were frequently flooded. Lewkowitsch[40] also reported that fishy butter is met with in Norway, being obtained from cows fed on fishmeal. In contradiction to the above, Weigmann writes that even in the case of intensive feeding of herring meal or whale meal, neither the milk nor the butter showed signs of fishiness. Platon and Olsson[42], and Ritter[43] reported that intensive feeding of young clover and alfalfa greatly increases the danger of butter made from such milk to develop the fishy flavor.

Piffard[44] advised that fishy butter may frequently be due to impure water containing the flavor, to which the cows have access, and to which he attributes the development of diatoms and algae, notably the Oscillaria. He also suggested that butter may take up the fishy flavor from salt that has absorbed it during storage from some other products. The transportation of butter in cars having previously carried fish or products with similar odor may also occasionally be responsible for fishy flavor in butter. Thus, in Great Britain and Ireland the law requires rail carriers to provide separate cars for the shipments of fish and butter.

Micro-organisms Causing Fishy Flavor in Butter.—Other investigators were able to trace the development of fishy flavor in butter to the activity of micro-organisms in the cream. Thus, Callaghan[45, 46, 47] reported that fishiness in butter was due to the mold Oidium lactis, and that when grown in conjunction with S. lactis in cream, fishy flavor resulted invariably. He also

reported that numerous shipments of unsalted Australian butter showed the fishy flavor upon arrival in London and that fishiness in unsalted butter was occasionally noted at the Australian ports of export. Davies[48] offers the explanation that these molds have the property of liberating considerable quantities of oelic acid which, during its insipient oxidation, may catalyze the oxidation of lecithin, leading to fishiness.

Harrison[49] classes the fishy flavor of butter with bitter, putrid and lardy flavors, the causes of which he attributes to the presence and growth of undesirable micro-organisms in the cream. Jensen[9] found certain species of yeast that give butter a fishy flavor. Klein,[50] speaking of oily, fishy and tallowy butter, holds that all these butter defects may well be considered specific forms of rancid butter, resulting from the action of bacteria. Hammer[51] isolated from a can of evaporated cream, which had developed a fishy odor, a bacillus of the Proteus group, which he named Bac. ichthyosmius. With this organism he was able to reproduce the fishy odor in milk, cream, and evaporated milk. When inoculated into butter, either direct, or into sweet or sour cream, however, the butter failed to show fishy odor or flavor. Similar negative results were obtained by Sommer[52] who reports that Bac. ichthyosmius failed to develop fishiness in butter.

Control of Fishy Flavor by Process of Manufacture.—The foregoing citations emphasize the multitude of channels, other than the method of manufacture, that may and occasionally do cause fishy flavor in butter. The possibility of these sources has been established and should not be overlooked. In some instances they may constitute the fundamental cause of the defect, while in others they may be contributory causes only, that promote the development of fishiness when other factors are present.

Our present knowledge and experience definitely indicates, however, that the fundamental cause of the fishy flavor in commercial butter has to do with and can be definitely controlled by the process of manufacture. The vast store of experimental results and of commercial experience, in this country and elsewhere, provides conclusive evidence that high churning acidity is the controlling factor in the development of fishiness in salted butter with age, and that the presence of certain metals, such as copper and iron, and their salts and oxides, greatly accelerates the changes leading to the defect.

As early as the year 1890 Storch[53] attributed the fishy flavor of butter to the practice of ripening cream before churning. The early experiments of Rogers,[54, 55] Rogers and Gray,[56] and Rogers, Thompson and Keithley[57] established conclusively the fact that salted butter made from ripened cream, raw or pasteurized, has a definite tendency to become fishy in storage, while salted butter made from sweet, unripened cream remained free from the defect. They also concluded that unsalted butter rarely, if ever, develops fishiness.

Supplee,[58] Cusick,[59] and Sommer and Smit[60] demonstrated that the fishy flavor is caused by the presence in butter of trimethylamine, which in turn is due to hydrolysis of the lecithin and the oxidation of the liberated choline, yielding trimethylamine which has an intense fishy odor. Sommer and Smit[60] further showed that these reactions are enhanced in the presence of acid and brine and that they are promoted by traces of such metals as copper and iron, which catalize the reaction. The mechanism of trimethylamine liberation in butter is explained by Davies[48] to be that of the action of organic peroxides on the choline residue of lecithin, causing a mild oxidation which is strongly catalized by traces of copper and iron. The acidity of butter churned from sour or ripened cream accelerates oxidation and the salt in butter has a solvent action on the lecithin, facilitating the reaction. Overworking increases the oxygen content and its dispersion in the butter, accelerates oxidation and also brings more lecithin into solution in the brine, thereby encouraging the development of fishiness.

Experimental trials and commercial experience over a period of years have demonstrated that a cream serum acidity of 0.35%, which is equivalent to a titratable acidity of practically 0.25% for cream testing 30% fat, eliminates the churning acidity of the cream as a cause of fishy butter. Lower churning acidities may further assist in the general keeping quality of butter. The desirability of low churning acidity is further emphasized by the experience of such butter exporting countries as New Zealand and Australia, who have found it advantageous to churn at an average acidity of approximately 0.09% and 0.12%, respectively.

The tendency of butter to develop fishy flavor, as affected by cream pasteurization, was experimentally studied in Switzerland by Ritter,[43] and in Sweden by Platon and Olsson.[42] Ritter's work was done in a commercial creamery receiving a good

quality of gathered sweet cream, averaging 30% fat, using the plate pasteurizer, and ripening the cream to 0.56-0.61% churning acidity. The pasteurizing temperatures of the experimental churnings ranged from 78 to 94° C. (172.4 to 201.2° F.) He reported the following results:

Temperature of Pasteurization °C.	°F.	Score of Butter After 42 Days	Flavor of Butter After 42 Days
78	172.4	13.92	Fishy
80	176.	14.96	Fishy
82	179.6	15.67	Fishy
86	186.8	17.19	One-half of lots were fishy
90	194.	17.75	Not fishy
94	201.2	16.91	Occasional lots fishy

Ritter reported that the creamery in which these experiments were made had persistent trouble with fishy butter, but after raising the pasteurizing temperature to 88-90° C. (190.4-194° F.) its fishy butter menace was largely eliminated. It is not clear from the report whether the above experiment involved salted or unsalted butter. The fact that unsalted butter is used almost exclusively in Switzerland suggests that the results refer to unsalted butter.

Platon and Olsson experimented with the Danish system of repasteurization of cream. The work was done in the Swedish experimental creamery. Part of the butter was made from milk received from the farmers and part from cream from a skimming station. The system of repasteurization consisted of heating the milk to 85° C. (185° F.), cooling it to the temperature of separation, and repasteurizing the separated cream at 185° F. Both, the plate pasteurizer and the ordinary flash pasteurizer (Danish type), were used. The cream was ripened to various acidities. The butter contained from 0.6 to 1.0% salt. These investigators reported the following results:

1. Out of 30 experiments, 23 of the control churnings were fishy in three weeks, while only six of the repasteurized churnings showed the defect.

2. The higher acid cream of all churnings produced more fishy butter than the lower acid cream.

3. The plate pasteurizer was more effective in preventing fishiness than the ordinary flash pasteurizer.

4. Lowering the temperature of repasteurization to 75° C. (167° F.) reduced the fishiness-preventing efficiency in the case of the plate pasteurizer, but not of the ordinary pasteurizer.

5. The results were considered sufficiently favorable to the system of repasteurization, to issue instructions to the creameries to repasteurize their cream at times when fishy flavor might be expected.

Prevention of Fishy Flavor in Butter.—In view of the known factors that enter into the development of fishy flavor in butter, prevention of the defect suggests the following precautions in manufacture:

1. Churn the cream at a cream serum acidity of 0.35% or lower. The correct titratable acidity of cream equivalent to this serum acidity for cream of different fat contents, is given in Table 19.

The danger of fishy flavored butter resulting from high acid, or ripened cream, is limited largely to salted butter. Unsalted butter made from cream of good quality, properly ripened, rarely develops fishy flavor. Cream ripening improves the keeping quality of unsalted butter.

2. Keep cream shipping cans and copper surfaces in plant equipment well tinned, so as to confine contamination of the cream with compounds of copper and of iron to the lowest possible minimum. The use of aluminum cream cans and of stainless steel plant equipment provides added protection against contamination with damaging metals.

3. If cream ripening and churning at a high acidity is contemplated, pasteurize the cream at 194° F.

4. Do not whip or overwork the butter.

5. High salt butter is more conducive to fishiness than low salt butter. Do not salt the butter excessively.

Woody Flavor.—This flavor defect is a rare occurrence in fresh butter, but is characteristic of the surface flavor of butter when it comes out of cold storage. Occasional instances of wood flavor in fresh butter have been traced to lack of proper treatment of new churns or of churns that have been lying idle for some time, stale water from wooden tempering tanks used for washing the butter, and butter salt stored in barrels of decayed wood.

In the case of storage butter (stored in paraffined tubs), the surface of the butter is practically always tainted with a more

or less intense woody, oxidized flavor. If the surface is not scraped before cutting and packing into the consumer's package (prints, rolls, etc.), its mixture with the mass of butter tends to depreciate the flavor and quality of the entire package. Neither the paraffining of the wooden containers (tubs or cubes), nor the parchment liner, are adequate protection against the woody flavor on the surface of storage butter. Casein coating has proved more effective than paraffine, and the use of "Parchfoil" liners (one sheet of aluminum foil between two thin sheets of parchment) has been found to eliminate the development of woody flavor on the surface of stored butter. For details see Chapter XVII on "Packing the Butter.'

Carton Flavor.—Butter sold in printed cartons occasionally shows an objectionable oily flavor, particularly in the surface layer. This so-called carton flavor does not come from the carton material, but has been found to be due to the oil contained in the ink that the carton manufacturer may use for printing the carton. It has been the general practice to dissolve or emulsify the dye that is used, in linseed oil or linseed preparation, known as reducing varnish. All linseed oil has a strong odor. In low grade oils the odor is particularly intense, penetrating and offensive. Cartons that are printed with this type of ink are prone to taint the surface of the butter. The tendency of such flavor damage is greatest with a comparatively "green" carton supply that has not aged long enough after printing to permit drying and expulsion of the volatile odors.

As the result of serious complaints and costly losses, some of the carton manufacturers have concentrated their attention on the composition of ink used for butter cartons, and these efforts have largely eliminated the danger of carton flavor in butter. In the presence of cartons suspected to cause carton flavor, the danger may be avoided by drying the carton stock in the creamery. Opening the packages received from the manufacturer, to permit circulation of air through the cartons, is of some assistance. Spreading them out on shelves in a warm room, with heated air circulation, is most effective. In such case care should be taken that the cartons are not heated excessively (not over about 85° F.), in order to avoid softening of the paraffine coating, that would damage the cartons and cause them to stick together.

DEFECTS IN BODY AND TEXTURE OF BUTTER

Body and texture refer chiefly to the physical properties of butter. A physically ideal butter is one that has a firm, compact body that will stand up well under unfavorable temperature conditions, and is free from visible moisture, and that has a waxy, plastic and spreadable texture, free from objectionable crumbliness, stickiness, salviness, greasiness, mealiness and grittiness.

The factors and combinations of factors that determine or influence the body and texture of butter are numerous. On the basis of our present knowledge, they have to do with the composition of the butter fat, structure of the fat globules, rate of fat crystallization in cream and butter, amount of liquid fat and size of fat crystals in the butter. Some of these factors are, in turn, related to certain phases in the process of manufacture, such as intensity of cream cooling, temperature of butter wash water, manner and intensity of working, and temperature at which the butter is held immediately after manufacture.

The science of the relationship between some of these factors, and their effect on body and texture, is generally understood, while that of other factors is as yet largely undetermined. The proper adjustment of the multitude of factors that influence the body and texture of butter, to the fluctuating character of the raw material, is further complicated by the usual endeavor, dictated by competitive expediency, of incorporating in butter the maximum percentage of moisture permitted by law.

Theories of the Mechanism of Seasonal Defects of Body and Texture of Butter.—It is especially such seasonal defects as an excessively hard and objectionably brittle and crumbly body, and a sticky texture, that have offered stubborn resistance to efforts at their solution. It may prove helpful, therefore, to precede the specific directions of manufacturing methods intended to minimize or prevent the appearance of these defects, by briefly enumerating the known facts and the theories that have been advanced relative to their probable causes and their most promising means of prevention, as follows:

1. The fat in cream that has been cooled to the usual range of the churning temperature (45 to 55° F., or even lower) still contains some liquid fat, i.e., the fat is present in partially crystallized and partially liquid form. This fact has been dem-

onstrated by the work of Van Dam,[61] Arup,[62] and Quagliariello.[63]

2. Butter likewise contains, in addition to crystallized solid fat, a liquid fat phase. This was shown by King[64] and by Van Dam and Burgers,[65] and King pointed out that it is the "free" liquid fat in butter that preeminently provides the continuous phase in the system "water-in-fat."

3. Butter fat is capable of, and does yield, fractional crystallization. This is a fact observed by every student of the properties of butter fat. It is fundamentally due to the fact that butter fat is a mixture of fatty glycerides of different melting points. When melted butter fat is cooled to successively lower temperatures, the high-melting point fats crystallize out first, and as the temperature is lowered, more of the lower melting point fats crystallize, but liquid fat can still be expressed at temperatures well below 50° F.

4. The proportion of liquid to crystallized fat in cooled cream and in butter depends on the proportion of high- and low-melting point fats present, and on the temperature to which the cream is cooled.

5. The proportion of high- and low-melting fats present is controlled by the composition of the butter fat, and this in turn is primarily affected by the season of the year, i.e., the feed of the cows. Summer feed increases, while winter feed decreases the proportion of low-melting point fats.

6. At a given churning temperature, therefore, winter cream and butter contain less liquid fat than summer butter. This seasonal characteristic of winter butter fat is often accompanied by excessive hardness, crumbliness and stickiness of butter, unless modified by suitable adjustment of the process of manufacture.

7. In general, not cooling winter cream to a temperature lower, nor holding it longer before churning than necessary to prevent excessive loss of butter fat in the buttermilk, tends to minimize the crumbly and sticky butter defect, but the limitations imposed by the danger of high buttermilk tests, do not permit of applying these conditions to the extent necessary to insure complete elimination of the defective body and texture.

8. It was shown by the work of Haglund, Wode and Olsson,[66] Wode,[67] Storgard[69] and Mohr and Oldenburg,[69] that

absence of the low cooling of cream, combined with the chilling of the granular butter with cold wash water (36 to 40° F.), yielded butter of good spreadability and free from crumbliness. Coulter and Comb[70] likewise reported that the above method eliminated excessive hardness, and objectionable crumbliness and also stickiness. Wilster, Stein and Stout[71] found butter so made to be more spreadable, and less crumbly, but pronouncedly sticky. Mohr and Oldenburg advanced the theory that the objectionable hardness and crumbliness of winter butter is due to the coarse size of fat crystals in such butter, and that the cold-washing of the granular butter assists in eliminating the factors responsible for this condition.

9. The use of cold wash water for winter butter is based on the theory that butter in which the fat crystals are and remain exceedingly small, has a soft, plastic, spreadable texture, while butter so made as to contain large, coarse fat crystals that will continue to grow in size after manufacture, has a hard, friable, crumbly texture, in a similar sense as snow (which is an aggregation of very small ice crystals) is soft and pliable, while a cake of ice is hard, friable and brittle.

To produce the permanently small fat crystals, winter cream is cooled only slightly so as to preserve the free liquid fat phase as much as possible prior to the washing of the butter. The granular butter is washed with very cold water because, according to the generally observed principle in crystal formation, the rapid cooling of a crystallizable liquid to a point below the saturation temperature, yields mass crystallization of exceedingly small crystals, while slow cooling to around the saturation temperature produces slower crystal formation, but larger crystals which continue to grow.

As applied to the washing of the granular butter with very cold wash water, this means that this sudden chilling causes mass crystallization of the liquid fat phase, yielding such a mass of very small crystals that the state of super-saturation is reduced to the state of saturation. This in turn prevents further growth of the fat crystals formed, they remain permanently small, hence the plastic texture of the butter. Such butter, while firmer at the churn, does not harden further in the cooler and is actually less hard twenty-four hours after manufacture than butter that was not chilled in cold wash water. On the other hand, butter washed in the ordinary manner suffers progressive crystal-

lization of the liquid fat phase. Fat crystallization and crystal growth continue, causing the butter to "set" (harden) when at rest after the working process, as shown by the results of Hunziker et al, given in Table 42, Chapter XVI.

10. In seemingly direct opposition to the cold wash water method is the procedure for the prevention of sticky butter, developed by Richardson and Abbott.[72] These investigators advocate quick cooling and immediate churning of the cream. In order to avoid excessive fat losses, the method necessarily involves cooling the cream to a relatively low temperature (about 8 to 10° F. below normal churning temperature). It further provides for wash water sufficienty cold to have the butter firm at the time of working, and for carrying out the operations of washing, working and removal to the cooler (at around 50° F.) rapidly, and without delay between operations.

Richardson and Abbott explain the effect of their method as follows: "When cream containing this type of fat is handled in a manner common to normal churning procedure, an excessive portion of the fat has crystallized at the time of churning. Too small a portion remains homogeneous to give the resulting butter the coherence and tenacity necessary for plasticity or spreading ability. When such cream is rapidly cooled from a temperature at which the fat is liquid, to the proper temperature of churning, and churning is commenced without delay, the fat at the time of churning is a solidified, more or less homogeneous mass, with a decreased tendency to separate into liquid and crystalline portions."

While differing in procedure and in theory advanced, yet the principle involved and the reaction attained by this method may not be dissimilar to those underlying the method and theory of Mohr and Oldenburg.[69] The distinction by Richardson and Abbott[72] between "homogeneously solidified fat and crystallized fat" appears necessarily to refer to a difference in particle size of fat crystals, "solidification" implying a system of very small crystals. In either method, therefore, the expressed effort is to convert the liquid fat phase into a mass of crystals of the smallest possible size, and to accomplish this by abrupt chilling that produces mass crystallization whereby, according to the theory of Mohr and Oldenburg, crystal growth associated with hardening of the butter after manufacture is prevented. The fundamental difference between the two methods lies in the fact that

Richardson and Abbott aim to accomplish this mass crystallization by rapid and low cooling of the cream, followed by immediate churning, while Mohr and Oldenburg defer it to the washing stage of the butter.

That deep-cooling of the cream has, in fact, a similar effect on the ultimate firmness of the butter as has chilling the granular butter with cold wash water, was demonstrated by recent experimental churnings conducted at the Danish Dairy Experiment Station.[101] The results reported show that cream cooled to 6°C (42.8°F) produced softer butter than cream cooled to 16°C (60.8°F).

Experimental trials with the Richardson and Abbott method, that have been reported by different investigators, and in which the directions were completely followed, are too few to justify conclusions. However, Richardson and Abbott reported that this method which is used in California creameries receiving cream from cows on alfalfa hay rations, has largely eliminated stickiness in their winter butter. This method has also been used over a period of three years by the author[73] in creameries in the middle west that were annually troubled with stickiness in winter butter, and has proved a successful means of overcoming this defect.

11. It is noteworthy that the European references to body defects in winter butter have to do exclusively with excessive hardness and crumbliness (Bröckelige Butter), and their theories of cause and prevention do shed considerable light upon the probable mechanism of crumbliness.

In this country, while excessive hardness and crumbliness are recognized defects characteristic of winter butter, it is particularly the sticky character that is in evidence and that is commercially objectionable.

In a strictly physical sense the two properties, crumbliness and stickiness, have nothing in common. Stickiness refers to the physical force by virtue of which one body or substance remains attached to the surface of another with which it has been brought in contact. It means adhesion, and in the case of sticky butter it means excessive adhesion. Crumbliness refers to a brittle, friable character. It has to do with absence of cohesion. In the case of crumbly butter it means excessive absence of cohesion. Sticky butter bores poorly because it refuses to cut "clean" and butter sticks to the back of the trier. Crumbly

butter refuses to yield satisfactory hotel slabs because the slabs crumble and fall to pieces. Intense stickiness, however, may give the impression of crumbliness, such as when the butter rolls up on the back of the trier. Neither defect permits of satisfactory spreadability.

Both defects are characteristic of winter butter. It is conceivable that in some cases the difference is merely a matter of choice of nomenclature by different individuals. However, the student of butter does recognize crumbliness and stickiness as two separate and distinct defects. While both may appear in the same piece of butter, and may result from similar general causes, such as predominance of high-melting point fats, they may be accentuated by different methods of manufacture, and yield to different treatments. In the case of sticky butter particularly, advanced lactation, associated with small size fat globules and increased amount and changed character of the milk proteins, may be a contributory factor.

12. The mechanism of bringing about stickiness in butter is not well understood as yet. Stout[74] visions the sticky butter defect as associated with the working of butter in which excessive fat crystallization has caused a shortage of liquid fat. He points out that liquid fat is needed for lubrication in working, and suggests that in the case of sticky butter, there is not a sufficient quantity of lubricating "free" fat present, thus causing a tendency for the fat globules to be bruised and torn by rubbing and crushing together and by scraping past each other, thereby resulting in a condition that gives the butter a sticky character.

It is well known that winter butter requires more working for the desired moisture incorporation, because of its increased content of hard fats. It is also the general observation that overworking yields softer butter. Storgard[68] suggests that this is due to the greater amount of "free" fat formed, due to the breakdown of the fat globules resulting from overworking. The mixing of their contents would thus increase the continuous fat phase, altering its characteristics, which may in turn be responsible, in part at least, for the tendency to stickiness in overworked butter and in winter butter.

13. The inadequacy of these explanations of the mechanism of defects in body and texture of winter butter is obvious. It suggests the need of further fundamental research on this subject. Yet, the theories briefly discussed in the foregoing

paragraphs may provide some suggestions helpful in emphasizing the importance of the details of the more specific directions for practical factory use, that follow.

Crumbly, Brittle Butter.—The tendency for a hard, brittle, crumbly texture is characteristic of butter made in late fall and winter. Most creameries are troubled with this defect to some extent during the winter season. The hotel and restaurant trade particularly objects to the brittle and crumbly character, because they find it difficult to cut such butter into neat patties, slabs or cubes for table use. Crumbly butter refuses to respond satisfactorily to the knife or wire when attempting to cut thin slices.

The theories relating to the mechanism of the cause and prevention of crumbly butter are discussed in preceding paragraphs under "Theories of the Mechanism of Seasonal Defects of Body and Texture."

Prevention of Crumbly Butter.—The crumbly character is attributed to abnormal hardness and short grain of such butter. This in turn is due to the predominance of high-melting-point fats in cream from cows fed on dry winter feed. Advanced lactation, yielding small size fat globules, and other characteristics of "stripper" cream, may further contribute to the conditions that cause the defect.

The addition to the ration of feeds that are known to increase the proportion of low-melting-point fats, provides the most fundamental means of minimizing or preventing the defect. This is true of such succulent feeds as corn-, grass-, or legume silage, or roots, also some of the concentrates high in oil, such as linseed meal, glutenfeed, etc. Since the average creamery operator lacks the opportunity to control and adjust the feed ration of the cows that provide his cream supply, he must rely on the proper adjustment of his methods of manufacture to avoid objectionable crumbliness of his winter butter.

Avoidance of low cream cooling temperatures and of prolonged holding of the cooled cream assists in minimizing the hard, crumbly character of winter butter. The cream should be cooled to a temperature no lower than is necessary to prevent excessive fat losses in the buttermilk.

The crumbly character can be entirely prevented if, in addition to avoidance of low cream cooling temperatures, the

granular butter is chilled thoroughly and uniformly with real cold wash water, such as water at 40° F. When using this method, it is important to chill all the butter uniformly, by keeping the wash water in the churn from 5 to 10 minutes. If the cream was cooled to excessively low temperature, the good effect of chilling the butter with cold wash water is largely lost.

The tendency for winter butter to be brittle and crumbly is further diminished by maintaining the creamery cooler at a moderate temperature, such as 50 to 55° F. This is particularly desirable in the case of print butter intended for the hotel and restaurant trade. The cautioning of hotels and restaurants to avoid unduly low refrigerator temperatures for their butter before cutting, in winter, is of further assistance in avoiding complaints due to brittle, crumbly butter.

Sticky Butter.—This defect refers to butter that refuses to bore or cut "clean." It sticks to knife or trier. It tends to show a ragged bore, and in the case of intense stickiness, it may "roll up" on the back of the trier, giving the impression of crumbliness. Similarly as crumbliness, stickiness is also characteristic of butter made in late fall and winter. Its appearance

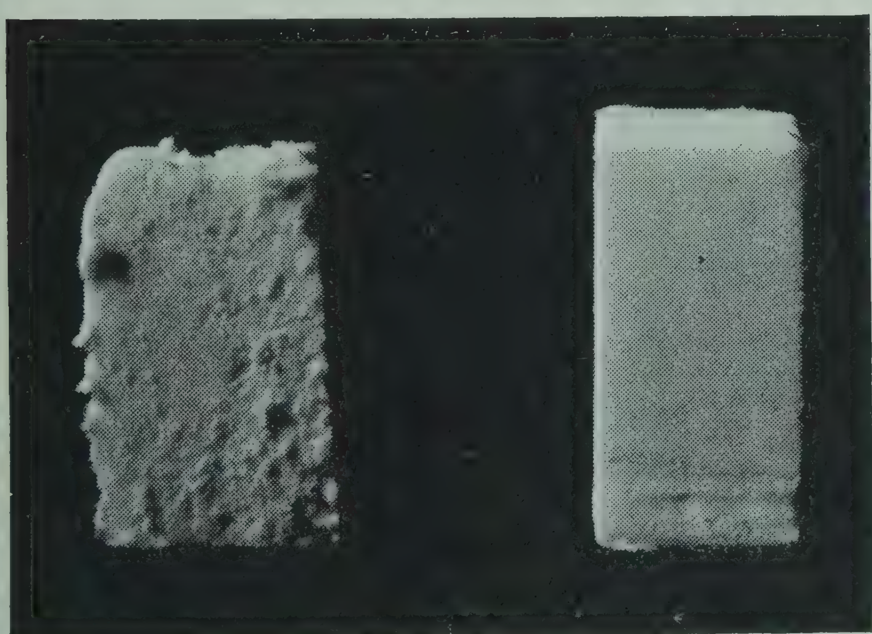


Fig. 115. Sticky butter (left) and waxy butter (right)
Courtesy of G. H. Wilster & R. E. Stout

is, however, not confined to winter butter alone. Sticky butter is severely criticized on the open market, where bulk butter is examined "over the trier."

Not infrequently stickiness and crumbliness are present in the same piece of butter. The similarity between the two defects in some cases suggests a distinction without a difference,

causing confusion in designation. Nevertheless, the two defects are separate and distinct. There is sticky butter that is not crumbly, and there is crumbly butter that is not sticky. The theories relating to the mechanism of the cause and prevention of sticky butter are discussed in preceding paragraphs under "Theories of the Mechanism of Seasonal Defects in Body and Texture."

Prevention of Sticky Butter.—The sticky butter defect of winter butter is atributed to the same fundamental causes as the crumbly butter defect; i.e., predominance of high-melting point fats in the cream from cows fed on dry winter feed. Alfalfa hay has been found particularly conducive to sticky butter. The peculiarities of the properties of "stripper" cream may also be involved.

In general, avoidance of low temperatures in cream cooling and of prolonged holding of the cooled cream, tend to minimize the defect. However, on account of the danger of excessive fat losses by this combination of procedure—high temperature of cream and short holding time—these precautions cannot be carried far enough to prevent stickiness in butter made from cream that produces intensely sticky butter by the common procedure of handling.

As indicated under "Seasonal Defects of Body and Texture," some investigators have reported successful prevention of stickiness by chilling the granular butter with cold wash water (temperature about 40° F.), in conjunction with not cooling the cream to temperatures lower than necessary to avoid excessive fat losses. This method has proved successful in preventing sticky butter in a sufficient number of cases to justify its application.

Another method that has been found effective in preventing stickiness in butter made from winter cream, is the procedure of churning immediately after cooling, as recommended by Richardson and Abbott.[72] The details of this method are briefly given below:

1. Cool the pasteurized cream rapidly to a temperature at which the butter will churn out in about 50 to 60 minutes. This usually requires a churning temperature about 8 to 10° lower than normal. The rapid cooling refers particularly to cooling from 110° F. on down, and it is recommended, in vat pasteuri-

zation, that the brine be turned on when the temperature has dropped to 110° F.

2. Churn immediately after cooling.

3. Wash the butter with wash water at a temperature of 3 to 4° F. below that of the buttermilk, if the butter is normally firm. If soft, lower the temperature of the wash water, as much as 10° F. if necessary, to give the butter a normal degree of firmness.

4. Complete all operations rapidly after churning. Do not delay between operations.

5. It is preferable to avoid cool room temperatures that are lower than 50° F.

6. In case the pasteurized cream was previously cooled, such as cream held over night, heat the cream to 110° F., hold for 15 minutes, then cool rapidly using brine, and proceed as directed under 1, 2, 3, 4 and 5. The purpose of reheating this cream to 110° F. and holding at that temperature for 15 minutes, is to remelt the fat completely, so as to produce recrystallization by rapid cooling immediately before churning. This is important.

7. The successful prevention of stickiness in butter by this method depends on carrying out the above details as directed. Each step is designed to avoid the formation of large fat crystals, i.e., to produce a crystal system so fine as to preserve the fat in as nearly as possible a homogeneous mass of theoretically almost amorphous structure.

Stickiness may be produced at any time of the year by overworking the butter, especially in the absence of free moisture, and with high-speed worker rolls. If the character of the cream is at all favorable toward stickiness in butter, overworking will intensify the defect.

Weak Body.—Butter is generally considered to have a weak body when it lacks in the desired firmness and standing-up property. Such butter usually shows signs of objectionable softening at ordinary temperatures.

The weak body is fundamentally due to a state of fat crystallization so incomplete as to cause an excess of liquid fat in the butter. This in turn usually results from faulty adjustment of the cooling temperature of the cream, or the holding time, or both, to the proportion of low-melting point

glycerides present in the butter fat. It is prone to occur when the proportion of soft fats is abnormally high, or in the absence of thorough cream cooling, or when churning cream immediately after cooling, without sufficient lowering of the temperature to which the cream is cooled.

In general, and excepting cream containing an abnormally high proportion of high-melting-point fats (hard fats), such as is occasionally the case with winter cream, the accomplishment of a satisfactorily firm body that will stand up well under unfavorable temperature conditions, requires the thorough cooling of the cream to a reasonably low temperature some time between the pasteurizer and the churn. Holding the cooled cream over night yields butter with better standing-up properties than churning short-held cream, and short-held cream (2 to 4 hours) makes butter with better standing-up properties than cream cooled to the same temperature, that is churned without holding.

Weak bodied butter results most often in the spring during the transition period from dry winter feed to succulent pasture. It is usually due to not following the change to grass cream and the increase in softer fats, by sufficiently prompt adjustment downward, of the cooling and churning temperatures of the cream. The defect can be readily avoided by proper attention to the changes in the character and color of the cream during the spring season.

Greasy Texture.—Butter may show a greasy texture when worked excessively while in very soft condition. In this soft condition, it does not tolerate much working without becoming greasy. The danger of greasiness is usually greatest in the case of abnormally rich cream insufficiently cooled, and churned and worked while too warm.

The proper cooling of cream is the most effective means of prevention. In the case butter does come abnormally soft, greasiness may be avoided by chilling the butter granules thoroughly with very cold water (ice water) before working.

Salvy Texture.—This defect occasionally occurs when greatly overworking butter that is in very firm condition. In most cases, however, such overworking, especially in the absence of free moisture, produces stickiness.

A salvy character may also appear independent of the work-

ing process, such as in the case of abnormally thin cream, containing small fat globules, in which high-melting-point fats predominate, and which has been exposed to excessively low temperature abnormally long. This combination of conditions prevails occasionally relative to winter cream. It usually is associated with an abnormal prolongation of the churning period (several hours) and the formation of small, round butter granules that require much further churning to gather into units of manageable size. The prolonged agitation, pounding, and grinding to which these granules are subjected, destroys their grain and results in butter of a salvy texture. Such butter, likewise, tends to be excessively high in moisture.

Abnormal churnings of this type, usually respond best to a considerable raise of the churning temperature, sufficient to make the butter come fairly soft. This will shorten the churning period to more nearly normal, and this in turn minimizes the mutilation of the butter granules and largely eliminates the tendency to salviness and high moisture.

Leaky Butter.—Butter that is termed leaky usually appears wet to the eye. When bored, it shows beads or small droplets of moisture on the plug, and the back of the trier looks wet. In definitely leaky butter the moisture droplets may be sufficiently large to drip from the trier. The fundamental objection to this defect is that leaky butter suffers excessive shrinkage in weight in transportation and in storage, due to loss of moisture by leakage. It will also show abnormal loss of weight during the operation of printing and of the prints after printing. In addition, leaky butter packed in carton boxes, may soak the container, damaging its appearance and its usefulness. While the tendency of butter to be leaky is most common in butter made in late spring and summer, the defect may appear at any time of the year.

The fundamental cause of leakiness in butter is incomplete or improper working. It is due to an open texture and lack of sufficiently fine dispersion of the moisture or brine in the mass of butter, causing the presence, and the progressive aggregation after manufacture, of droplets and larger units of moisture, loosely held in the cavities and capillaries of butter with an open texture. Butter worked to a dry body is not and does not become leaky.

While the character of the butter fat and many of the steps in the process of manufacture affect the tendency of butter to show leakiness, they do so largely only insofar as they control the extent to which butter can safely be worked without damage to body, or without danger of excessive incorporation of moisture.

Thus, the tendency, well-known by the experienced butter-maker, for butter that comes soft and slushy, to be leaky, is not due to the softness of the butter as such. On the contrary, soft butter mixes with and holds its moisture better than hard butter, as shown by the results of Hunziker, Mills and Spitzer,[75] and Dahlberg.[76] The reason why soft butter is more prone to be leaky than hard butter is that soft butter takes up moisture so readily and drains so poorly that it usually cannot be worked sufficiently to insure the fine dispersion of its moisture and the compactness of texture necessary for freedom from leakiness, without danger of excessive moisture.

In commercial butter manufacture the most common cause of insufficient working and leaky butter is that there is more water in the butter, or free water in the churn, at the time of working, than is necessary to provide the desired moisture content in the finished butter, when all the moisture in the churn has been taken up by the butter. Hence the working must be stopped before all the moisture is thoroughly incorporated, in order to avoid excessive moisture in the finished butter. The butter, therefore, is not sufficiently compact to hold its moisture satisfactorily, and shows a leaky character. This condition occurs most often with grass butter. It can be readily avoided by more thorough cooling of the cream, efficient draining of the granular butter that assists in systematic moisture control, and working the butter to a compact, dry body. In case the butter does come soft, the chilling of the granular butter with cold water, thorough draining and proper working will prevent leakiness.

In addition, it is important to realize that firm butter requires more intense working to prevent the leaky defect than soft butter. Dahlberg,[76], studying the effect of temperature of wash water on the tendency to make butter leaky, found that cold-washed butter lost more weight by leakage than butter washed with warm wash water. He, therefore, concluded that cold wash water causes leaky butter. Under the conditions of

the experiment (working all butter the same), such would necessarily be the case. On the other hand, if the cold-washed butter had been given the amount of working that the firmer butter requires, the results would have been reversed. The firming of soft butter with cold wash water, followed by thorough working, prevents leakiness in butter.

Other conditions that make for leakiness in butter are: overloaded churn, high salt content, and addition of water near the end of the working process. Crowding the working capacity of the churn decreases its working efficiency and makes uniform working of the entire churning difficult, thereby increasing the tendency for butter to be leaky. Tests by Dahlberg[76] show that even normal size churnings averaged greater weight loss due to leakiness than undersized churnings.

Salted butter is more subject to the leaky defect than unsalted butter, and high-salt butter is more so than low-salt butter. The salt tends to disturb the stability of the system water-in-fat, owing to its affinity for moisture. This does not mean that leakiness in salted butter is unavoidable, but it does emphasize the need of more thorough working of salted butter, insuring complete solution of the salt, fine and uniform dispersion of the brine, and a close, compact body. Heavy-salt butter requires more intense working than light-salt butter.

Leaky butter is prone to result from addition of water late in the operation of working. This occasionally happens in moisture control when, toward the end of the working process, the moisture content is found low and more water is added to bring it up. Unless the working in such case is continued sufficiently long to properly disperse and incorporate the added water in the butter, such butter will show a leaky tendency. Rough handling in transit, especially when in soft condition, increases weight loss of butter due to leakage of moisture.

Gummy Butter.—This defect applies to butter which, when placed in the mouth, does not melt readily. It sticks to the roof of the mouth and gives the impression of gumminess.

This type is characteristic of butter made in those sections of the South where cottonseed products constitute the major protein portion of the feed ration. The defect is more noticeable in winter butter from the South, because of heavy feeding of cottonseed meal, or hulls, or both, in conjunction with dry roughage. In summer, green pasture and other suc-

culent feed appear to offset, in part at least, the effect of cottonseed products in the feed ration. Summer butter from the South, in general, is not objectionably gummy.

The gummy character is believed to be due to the abnormally firm condition of the butter fat, caused by the presence of an excess of high-melting-point fatty glycerides in butter fat from cows that are on rations rich in cottonseed products. Kuhlman and Gallup[77] reported that a ration exclusively of cottonseed meal and prairie hay, fed ad libitum, produced a harder butter fat with higher melting point and slightly lower iodine value than when molasses beet pulp was added to the ration. Keith, Kuhlman, Weaver and Gallup[78] found that for normal churning time and correct working, it was necessary to churn cottonseed meal cream (heavy cottonseed meal ration), at a churning temperature 6° F. higher, and use a correspondingly higher wash water temperature than for normal feed ration cream. Likewise, the working had to be increased to 124 revolutions. These results are in agreement with Hunziker's observations[79] in commercial butter manufacture in the South. These methods do not, however, eliminate the gummy character of butter made from cream produced by the heavy feeding of cottonseed products.

Keith, Rink and Kuhlman[100] further found that gumminess in butter resulting from heavy feeding of cottonseed meal is influenced by the time the cooled cream is held before churning. They reported that "cream held four hours produced a pronounced gummy body. This defect was less noticeable when cream was held only two hours, and was not evident when the cream was churned in less than one hour after cooling.

Mealy Butter.—Butter that is criticized as being mealy lacks the smooth, pleasing waxy texture of well-made butter. It conveys to the palate the impression of a mealy character, suggesting the presence of corn meal or sawdust. Hunziker[80] found that mealiness may result from either one of the following two causes: a hardened condition of particles of casein, and a grainy condition of crystallized fat.

Mealiness attributable to the casein is most likely to occur in butter made from sour (high acid) cream, that is improperly neutralized with lime. When the lime is added to the sour cream dry, or in too concentrated suspension, or is not dis-

tributed quickly and uniformly throughout the body of the cream, a considerable portion of the lime particles appear to combine with the sour casein, forming minute particles of insoluble calcium caseinate. In subsequent pasteurization, these casein-lime particles contract and harden, giving both the cream and the butter a disagreeable rough, grainy, mealy character. This action on the casein is intensified by prolonged vat pasteurization and at high temperatures.

When the butter fat is the cause of mealiness, the defect is usually due to the cream having been allowed to "oil-off" at some stage in manufacture. When such cream is being cooled, this "oiled-off" fat crystallizes in granular form and apparently without the mellowing influence that results from its natural emulsion with the milk albuminoids. The character of these minute particles of solid, crystallized fat suggests practically pure butter fat. Their presence gives the butter a grainy, mealy character.

This type of mealiness may result from prolonged heating to and at the pasteurizing temperature, delay of holding warm cream in the forewarmer before pasteurizing, delayed cooling of the pasteurized cream, especially between the melting and solidifying points of the butter fat (within the range of about 100 to 65° F.). Mealiness also almost invariably appears when frozen cream is thawed out by setting the cans in hot water (120° F. or higher), because such procedure invites copious "oiling-off" of the fat. The addition of an excessive amount of butter oil to the cream further promotes the appearance of mealiness in butter.

Prevention of Mealiness in Butter.—Attention to the following precautions usually eliminates the danger of the mealy defect:

1. Do not heat sour cream above 90° F. before neutralization.

2. Dilute the cream neutralizer properly and distribute it in the cream quickly and uniformly. See Chapter X also on "Neutralization."

3. Do not underfeed the flash pasteurizer, and provide such connections and facilities for vat pasteurization as to insure normal rapidity of heating and cooling. Do not hold the cream at pasteurizing temperature more than 30 minutes, and keep

the vat coil revolving during heating, holding and cooling. Avoid delay in cooling within the temperature range of 100 to 65° F. Keep vat coil and connections free from obstructions.

4. Do not hold warm cream in the forewarmer excessively long before pasteurization. In case of unavoidable delay, cool it to about 65° F., even if necessary to pump it into vat. In case of slow arrival of cream receipts, it is preferable to "hold up" "dumping" until enough cans have arrived to fill the forewarmer.

5. In case of frozen cream, thaw out by setting cans in water at not exceeding 95° F. Thawing out may be expedited by passing a small stream of water (95° F.) continuously through the tank that holds the cans of frozen cream.

6. If melted butter (butter oil) must be added to the cream, limit the amount to 60 lbs. per normal size churning (2,000-2,500 lbs. of cream).

Gritty Butter.—This defect refers to butter that grits between the teeth. In most cases the grittiness is due to the presence of undissolved salt. See Chapter XVI on "Salting Butter." Occasionally the grittiness is caused by the presence in butter of insoluble foreign matter, such as particles of sand from roily water used in washing the butter, or to particles of lime from improper neutralization or because of a poor quality of lime neutralizer. The presence of milkstone or burnt casein from incompletely cleaned heating surfaces, or of fine chips of glass enamel from damaged enameled equipment, may also be responsible for the gritty character.

Grittiness in butter, regardless of source, is severely criticized, both by the trade and the consumer.

DEFECTS IN THE COLOR OF BUTTER

The ideal color of butter ranges between a straw color and a golden yellow color, according to market requirements. It must be uniform from churning to churning, and the color must be solid, that is, it must be of the same shade or intensity throughout the body of the butter.

As shown by Palmer and Eckles[81] and Palmer[82] and discussed in Chapter XV under "Addition of Butter Color," and in Chapter XXI, on "Properties of Butter Fat," the natural yellow color of cream and butter is derived from two classes of yellow pigment, the carotene and xanthophyll.

Lack of Uniformity of Color between Churnings.—The trade and the consumer are critical in their demand of uniformity of color between different lots. The consumer has a natural preference for the shade of color to which he has become accustomed. In addition, a change in color may suggest to him that the butter is not genuine or that it is of inferior quality, and this suspicion not infrequently causes him to find diverse other faults with the product, imaginary or otherwise.

Occasionally the natural color of June butter is criticized for its intense yellowness. In general, however, the fact that grass butter is naturally yellow, is not unknown to the average consumer, and he expects summer butter to be golden yellow, and accepts it without complaint. The majority of complaints on color of butter occur during the winter season, when butter is expected to be of somewhat lighter color. It is unnatural variations and too high color of this butter (occasionally brick red), due to the excessive use of artificial coloring, that are mostly objected to. These occurrences usually have to do with errors in the calculations of the amount of butter fat in the churn, or of the exact amount of artificial color that is needed. Variations in the coloring strength of the artificial color itself may be a contributing cause.

The amount of working that is given the butter and the salt content also affect the intensity of its color to some extent.

Darkening of the color of butter usually also occurs on the surface of butter upon prolonged exposure to air. At ordinary temperature, this darkening progresses rapidly. It is principally due to the evaporation of moisture from the surface. For details see Chapter XVI under "Effect of Salt," and "Effect of Working, on the Color of Butter."

Bleached Butter.—Because of the growing demand on the part of certain trade for a lighter color of butter, efforts have been made to bleach the butter by chemical means. The bleaching action is usually associated with oxidation of the butter fat. There are numerous chemical compounds available that have a bleaching effect on the color of butter, some of which have been tried out. To these belong chemicals that liberate chlorine, also Benzoyl peroxide. The addition of such compounds to cream or butter, or to other food products, is contrary to pure food regulations. It is objectionable, in addition, because these

chemicals have a destructive action on vitamins, particularly vitamin A, and because they impair the flavor of the butter.

Other efforts to reduce the color of butter have led to the use of pigments of other colors, such as chlorophyll, for the purpose of covering up or bleaching the butter yellow. Experiments by Hunziker and Cordes[83] with this type of so-called bleaching compound added to June butter at the rate of 1.5 oz. per 100 lbs. of fat, showed that the color of the butter did not become lighter, it merely changed to a greenish tint. The compound likewise affected the flavor of the butter, giving it a cottonseed oil character.

The color of butter can be materially reduced without recourse to chemical compounds, however, by decreasing the size of the water droplets in the butter. This is made possible by more intensive working of the butter. This in turn requires greater initial firmness of the butter fat, such as may be attained by deep cooling of the cream, or by chilling the butter granules with very cold wash water (ice water). Since it is largely only the high color of summer butter that is criticized in some trade channels, the danger of objectionable crumbliness resulting from such excessive chilling is negligible.

It appears pertinent here to emphasize that yellow is the natural trade mark of butter, that distinguishes butter from other food oils and fats. It is manifestly logical, and to the best interests of the industry and the farmer, to preserve this trade mark, by concentrating our efforts on a character of consumer education that will stimulate, not only consumer acceptance, but consumer demand for butter with natural yellow color.

Dull, Lifeless Color.—The normal color of well-made butter, regardless of shade of yellow, is definite and bright. It has "life." The color of some butter lacks this character. It is indefinite, dull, lifeless. The dull color is characteristic of overworked, high moisture butter. The broken-down grain, the large amount of moisture in the form of finely dispersed droplets and the relatively high air content in the form of minute bubbles, associated with over-worked butter, hide the natural yellow color of the butter fat and rob the butter of its normal bright lustre, giving it a dull appearance. The lifeless character in such instances is usually aggravated in the case of butter that was originally firm, because such butter requires particularly intensive working for the successful incorporation of high

moisture. Coulter and Combs[70] report that the color of butter that had been chilled with very cold wash water (temperature 32° F.), lacked lustre and its body resembled suet.

Mottled and Wavy Butter.—Unevenness of color in the body of butter is shown in the form of streaks, waves and mottles. Streakiness or waviness refers to a condition in which the unevenness in color shows in the form of layers of waves of different shades of yellow. The color in the layer or wave itself, however, may be uniform. In the case of mottles the butter is dappled with spots of lighter and deeper shades of yellow throughout its body.

Unevenness in color, and especially mottles in butter, are a serious defect from the standpoint of its market value. Although it is not related to, nor does it affect the flavor or keeping quality of the butter, this defect is severely criticized by the trade. Butter that is mottled or wavy is penalized in score and in price.

Causes of Mottles and Waves in Butter.—It was shown by the work of Storch,[84] Sammis and Lee,[85] and Hunziker and Hosman,[86] that unevenness of color, such as appears in the form of mottles and waves, is primarily due to lack of uniformity of size and of distribution of the water droplets (or brine droplets) in butter. This in turn is chiefly caused by insufficient working or by lack of uniformity of working. Hunziker and Hosman[86] and Boysen[87] demonstrated that both the size and the distribution of the water droplets in butter are influenced by the salt and can be controlled by the process of working. The mechanism of the conditions and reactions that cause mottles and waves is fundamentally as follows:

1. The whitish, opaque dapples in mottled butter are due to localized sections of innumerable, very minute water droplets. The countless surfaces, and sharp curvatures and angles of this great multitude of exceedingly small droplets do not permit the rays of light to penetrate the butter sufficiently to reveal the natural color of the butter fat, which is clear and yellow. They are bent back, refracted and deflected, giving the butter an opaque, whitish appearance. The opacity is further intensified by the difference in refractive index between butter fat and water or brine.

Size of Water Droplets in Light and Dark Portions of Mottled Butter

Magnified X 740

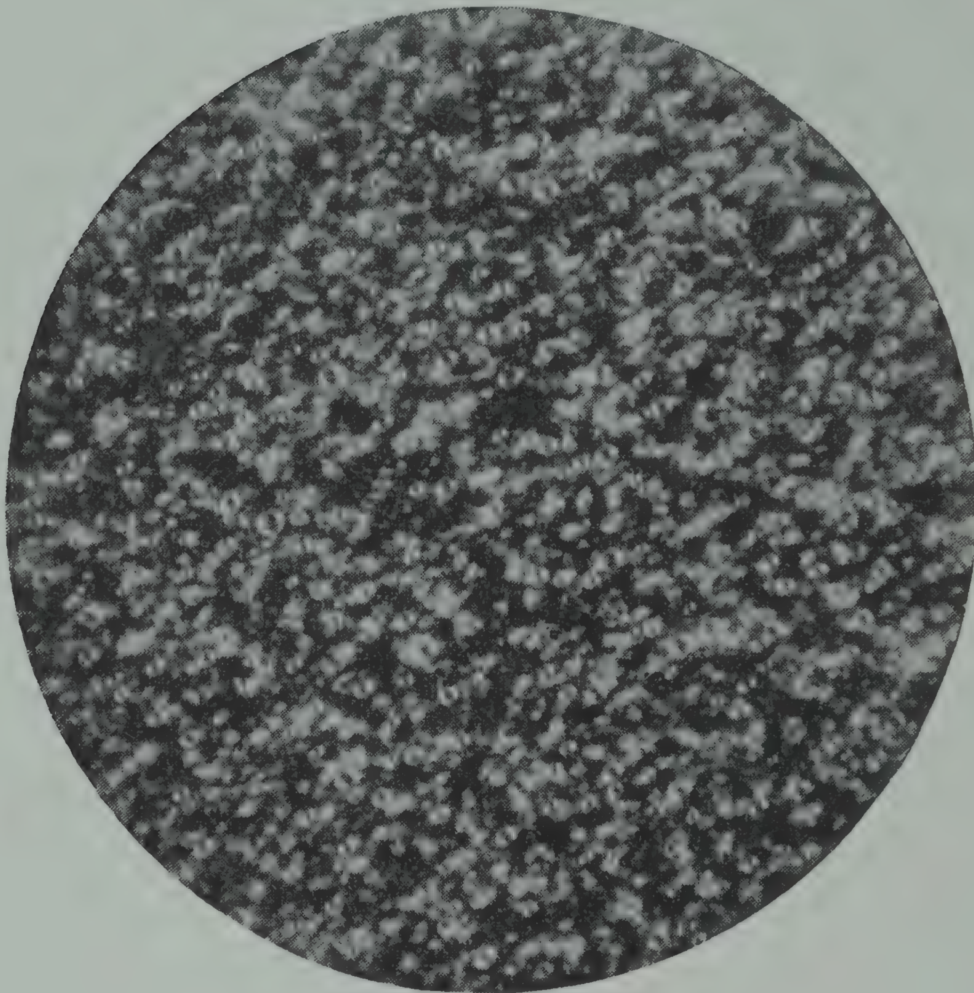


Fig. 116. Light portions

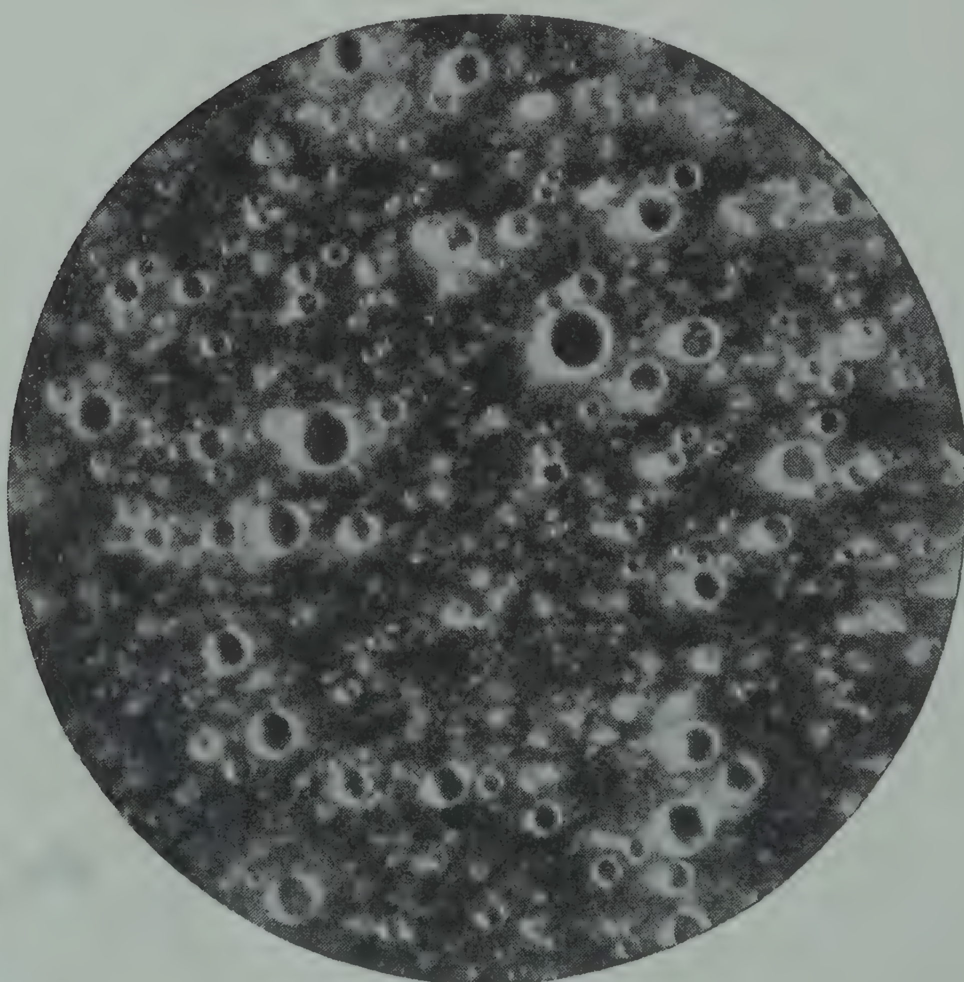


Fig. 117. Dark portions

2. The clear, deep yellow blotches of mottled butter are caused by the relatively smaller number and larger size of water droplets, or by their complete absence. Both, the absence of water droplets and the presence of few but large droplets, eliminate or minimize, respectively, the refraction and deflection of the light, permitting the rays to penetrate sufficiently to show more nearly the true color of the butter fat. The butter thus appears more translucent and deeper yellow in color.

3. The reason why salted butter invariably shows a clearer and deeper yellow color than unsalted butter lies in the fact that the salt, due to its salting-out action on the curd and to its affinity for water, renders the water-in-fat emulsion less complete, liberating some of the more loosely held droplets and drawing them together into larger aggregates.

4. The reason why unsalted butter has a lighter and more opaque whitish color, and that it seldom, if ever, shows mottles, lies in the fact that its emulsion system is not disturbed, its fine dispersion of water droplets remains intact, and the entire mass of butter retains its whitish opacity. The color, therefore, remains solid.

5. Salted butter, when insufficiently and unevenly worked, invariably becomes mottled upon standing (in six to twelve hours), because in such butter the fusion, dispersion and emulsification of brine and water are incomplete. Owing to the difference in concentration, equalization or interchange of the brine and water sets in by osmosis. The resulting migration of water and brine droplets causes the more loosely held droplets to run together, forming larger and fewer aggregates, and giving the portion of the butter where they are localized, the appearance of a more translucent and deeper yellow color.

This migration and running together of droplets simultaneously also uncovers and brings to view the localized sections of innumerable, more firmly held, very small droplets, which give the appearance of opaque whitish dapples. The presence of the deep yellow blotches and the opaque whitish dapples thus constitutes the composite color effect in butter, i.e., mottles.

6. Streaky or wavy butter is caused by uneven working of different portions of butter of one and the same churning, either due to a faulty condition of the workers or an overloaded churn. Those portions of the churning which receive the most working

have the lightest color, because the more the butter is worked, the smaller become the water droplets, and the smaller the water droplets, the more opaque and the whiter is the butter.

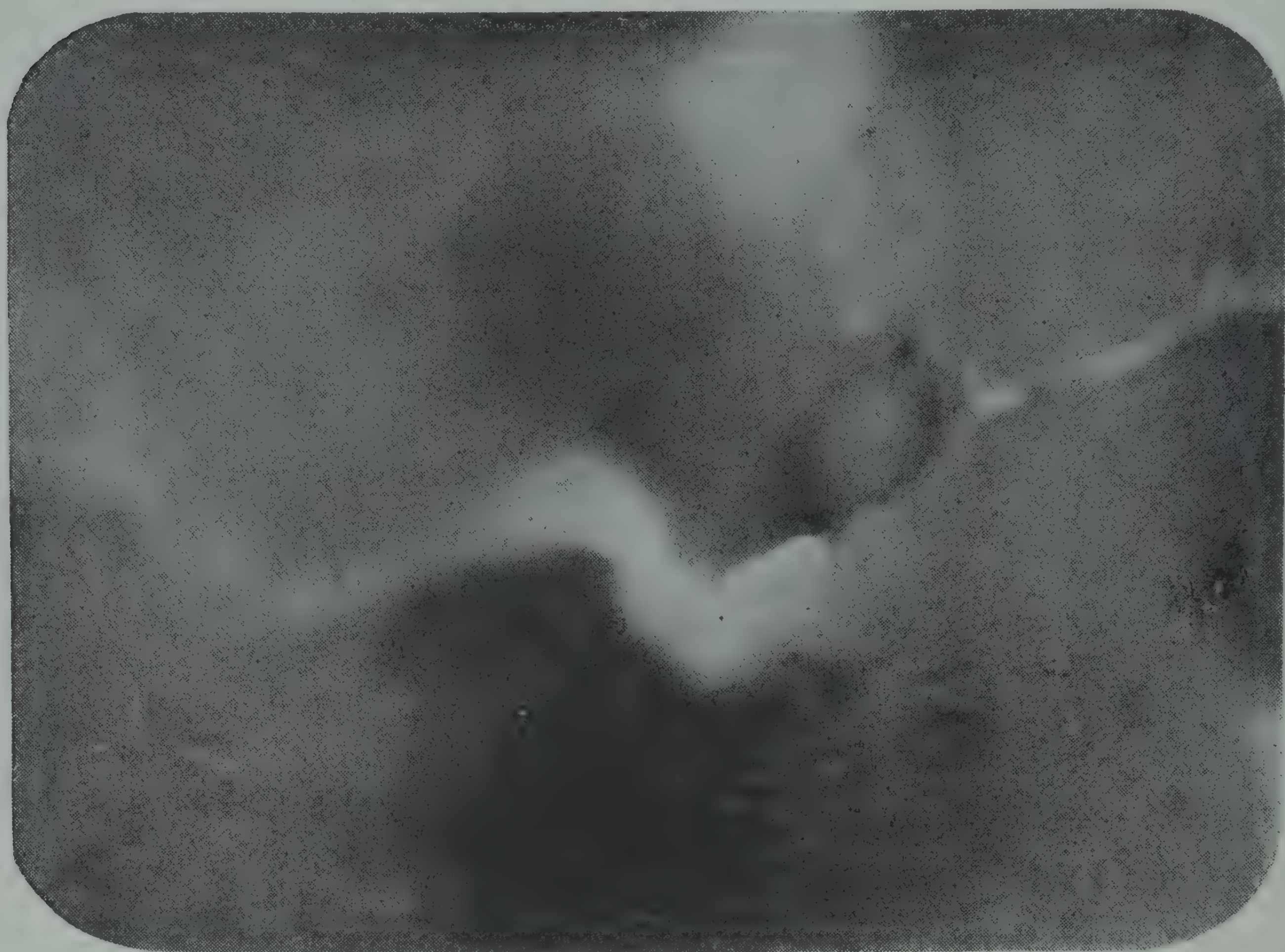


Fig. 118. Fissures in underworked salted butter, showing migration of water (Magnified X 110)

7. Unevenness of color, streaks, and mottles may result from any other cause that brings about an uneven distribution and size of the moisture droplets in different portions of the butter, such as may be the case in tubs or cubes containing remnants of butter from more than one churning, by faulty reworking of remnants in the churn with fresh butter, by the action on butter of certain butter cutting machines, by holding slabs of salted butter in water, or by the evaporation of moisture from the surface of butter.

Prevention of Mottles and Waves in Butter.—In order to successfully avoid the appearance of mottles and waves in butter, attention to the following precautions has been found helpful:

1. Keep churn and workers constantly in good mechanical repair. Make sure that the workers are correctly set and properly adjusted, and that they are free from slack, and do not slip.

In churns with more than one roll, the workers must be so set that, when in operation, the ridges of one roll nest with the grooves of the opposite roll. If so set that ridge meets ridge and groove meets groove, the working is very uneven, inviting mottles. It is important also to keep the wood in the churn drum in such condition as to prevent the tendency of butter to stick. Butter sticking to the churn misses some of the working action.

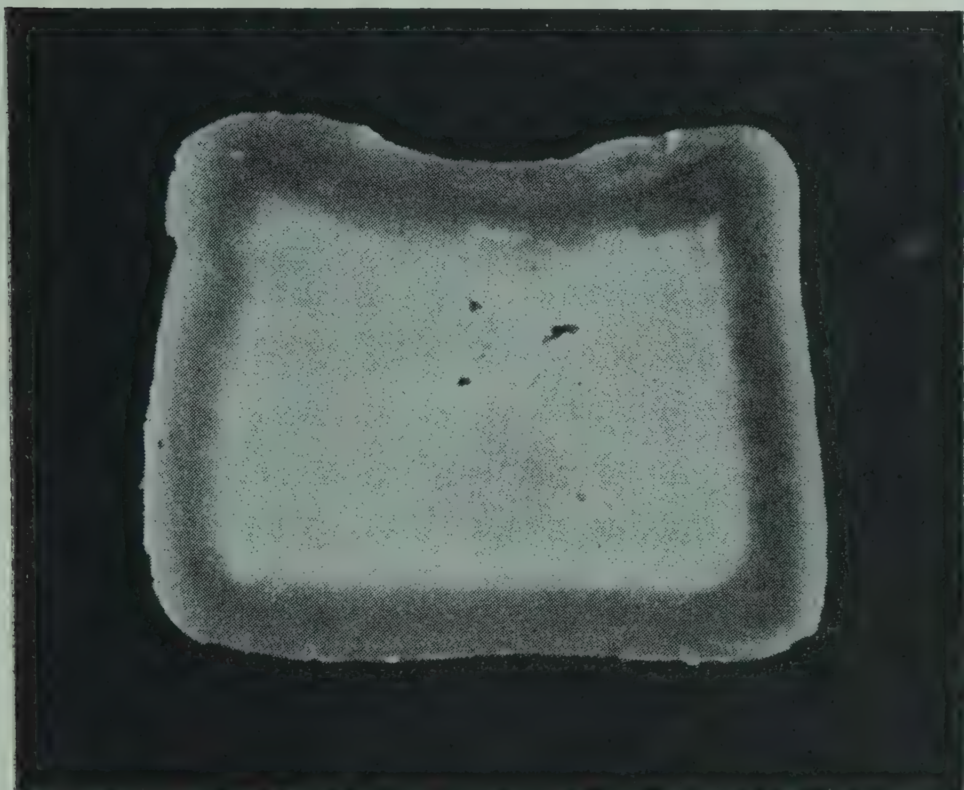


Fig. 119. Unsalted butter held at room temperature for 30 days, showing deep yellow border due to evaporation of moisture, while interior retained original light color; moisture in surface layer was 1%, in interior 16%

Waviness in butter has been definitely traced to a sticky churn in some instances. See "Treatment of Sticky Churn," Chapter IV.

2. Do not overload the workers. An overloaded churn needs more revolutions with the workers in gear than a churn not overloaded. But at best, such working is prone to lack in uniformity.

3. The butter must be worked sufficiently to dissolve the salt completely and to bring about maximum fusion of brine and water, and a fine state of dispersion of the moisture droplets, during the working process. The working operation is the only phase in butter manufacture that can accomplish this condition of solution, fusion and dispersion. If this is not accomplished before the butter is removed from the churn or butter worker, the subsequent appearance of mottles is unavoidable.

4. The firmness of the butter granules has a very marked effect on the amount of working required to prevent mottles.

The firmer the butter, the more working it needs to reduce it to the plasticity that makes for maximum division, uniform dispersion and thorough incorporation of the moisture droplets. Creameries receiving cream from sections where heavy feeding of such feeds as cottonseed products produce abnormally hard butter fat, frequently find their butter to show variegated coloring suggesting "measles." Invariably this defect is eliminated by more intense working. In some cases it may be necessary to increase the number of revolutions worked to 125—150. Such butter generally tolerates more working without damage to body.

5. The amount of salt added influences the amount of working necessary for complete solution of salt and dispersion of brine. High-salt butter requires more working to prevent mottles than low-salt butter.

6. The reworking of cold, hard remnants with soft, fresh butter usually leads to mottles and streaks. In case of several churnings of similar grade on the same day, the remnant of each churning may be reworked with the next succeeding churning. The remnant of the last churning of the day is preferably cut into prints for local consumption. If this is not practicable, the remnant may be added to a churning on the day following, by first tempering it to the approximate softness of the fresh churning. Another means of eliminating remnant butter as a source of mottles is to remelt the remnant in the cream of a new churning, returning it to the forewarmer.

7. When cutting butter for prints or rolls, with butter cutting machines that use the Archimedean screw, the butter should be tempered to a uniform consistency. In case of visible variations in color between different lots, mottles are best avoided by assorting the lots according to color and running all lots of the same color through the machine together. It is advisable to precut the butter for the cutting machine immediately before printing, in order to avoid surface darkening of the precut slabs.

8. Do not use brine-soaked parchments for wrapping unsalted butter, nor water-soaked parchments for wrapping salted butter. For unsalted butter, treat the parchments in boiling hot water. For salted butter, treat the parchments in concentrated, boiling hot brine.

Oil Spots in Butter.—Butter, otherwise of uniform, solid color, occasionally shows spots of clear deep yellow color, usually known as oil spots. This defect is due to conditions somewhere in manufacture, that permitted oiled-off fat to solidify as nearly pure butter fat. It may be caused by the presence of an excessive amount of remelted butter (over 50 to 60 lbs. per churning) or by the reworking of remnants that are in a soft, semi-melted condition, with normal butter, or to oiling-off in the churn due to hot water reaching the cream or butter through the wash water line such as due to leaky valve in steam connection, or to the use of a butter tamper that was soaked in hot water without chilling before use. The means of prevention of oil spots in butter are self evident.

Yellow Specks in Butter.—This is a rare defect and yet occasionally it does occur and cause trouble. When these specks are of an orange yellow, as is generally the case, they are usually traceable to sediment in the artificial butter color used. The defect occurs most readily at times when the supply of butter color in the drum is nearly exhausted. Some butter colors do tend to form a slight sediment, which settles to the bottom of the drum, so that the last remnant drawn may contain some of this sediment. In such case, it is wisdom to discard the drum remnant.

White Specks in Butter.—Butter occasionally is permeated with a multitude of small white specks. This condition is due to the incorporation of small particles of coagulated casein. The defect is easily preventable and should not occur when proper attention is given to the handling of the starter and the cream. Its most common cause is over-ripe starter, over-ripe cream and cream that has been allowed to dry on the surface due to lack of stirring during the ripening process. If the starter is added before it is overripe and has formed a firm curd, or if the coagulum is thoroughly broken up by stirring or pouring and the starter is strained into the cream, if the cream is properly stirred during the ripening process so as to prevent its drying on the surface, if it is not over-ripened, and is strained into the churn, there is usually no danger of white specks in butter. Starter should always be strained into the cream and cream strained into the churn.

The occasional appearance of white specks in butter may

be due to the cream strainer in the churn becoming clogged and flowing over, or to emptying the accumulated material caught in the strainer, into the churn, either through accident or through ignorance.

Whitish particles of diverse size may also appear in the butter as the result of scales of milkstone and dried casein from flash pasteurizers, the heating surface of which is not daily completely freed from all remnants of cream.

Green Discoloration of Butter.—Green specks or spots, other than those described under "Moldy Butter," occasionally appear on the surface or in the interior of butter. The green coloration usually radiates from a speck, and appears in the form of a ring or circle which grows larger with age. Microscopic examination by Hunziker and Hosman[88] showed these specks to have a metallic lustre, and chemical analysis indicated that they are tiny particles of copper or alloys containing copper.

When these metallic specks that cause the green discoloration, are confined to the surface of the butter prints, their source can usually be traced to the parchment wrapper. In such case recurrence is readily avoided by examining the parchment wrap supply and discarding all sheets that contain metallic specks.

When the green discoloration is observed in the interior of the butter, the cause usually lies in copper contamination from plant equipment. In this case the usual sources are worn brass bearings, or brass rotors in cream pumps, minute filings being cut out and carried into the butter by the cream. Occasionally copper wires (can seals) may accidentally gain access to the cream and be ground up in the cream pump. Or, a can cover may accidentally drop upon the coil in forewarmer or vat and become wedged between coil and side of container, causing metal shavings to be cut from the revolving copper coil. Or, the strainer on top of the forewarmer or vat may sag, scraping the revolving coil.

The copper particles are corroded by the salt and acid of the butter, causing verdigris and copper salts, which are responsible for the green discoloration in the butter. The defect is usually not limited to its objection to the eye. The oxidizing and catalizing action of the copper turns the butter strongly tallowy in taste and odor, and bleached in color. The tallowiness and bleaching, once started, usually spreads throughout the entire mass of butter.

This is a very damaging defect when it occurs, and any signs of green discoloration, no matter how seemingly trifling, should be followed-up by prompt and thorough examination of parchment wrappers and plant equipment, in order to forestall the possibility of more serious trouble.

Occurrence of an abnormal greenish-gray color in Australian butter was reported by Ramsay, Brown and Randell.[89] The results of their investigations suggest that aphis infestation of the feed was responsible for the defect. While the exact mechanism producing the green color escaped detection, it was definitely shown that none of the cows fed on fodder, free or practically free from aphides, produced butter with the abnormal color.

Specks of Iron in Butter.—Iron particles usually are of dark brown or black color. The sources of iron particles in butter are similar to those of copper, i.e., parchment wrappers, and plant equipment, and their elimination calls for similar precautions.

Iron or iron rust particles will oxidize butter and cause it to become tallowy and bleached in a similar manner as do copper particles, except that instead of a green discoloration, the vicinity of iron specks turns white and sometimes brownish.

Iron rust from rusty churn boltheads, or from sand papering rusty tub hoops and permitting some of the rust particles to gain access to the interior of other tubs when subsequently nested, have been found causes of the presence of iron specks in butter.

Pink Color of Butter.—The development of a pink color on butter is uncommon. While certain micro-organisms, particularly certain species of yeasts, that yield pink colored pigments, are capable of growing on butter, the occurrence of commercial butter with a pink color resulting from microbial action is practically unknown.

Hunziker, Cordes and Nissen[90] investigated the cause of intense pink coloration of print butter returned by the trade. The butter prints resembled bricks of strawberry ice cream, and their surface was strongly tallowy. Bacteriological analysis showed complete absence of pink colonies. In fact, plate counts of the surface scrapings showed the butter to be practically sterile.

A search for recorded occurrences of pink color in butter and butter substitutes revealed several instances of pink colored oleomargarine that was returned to the manufacturer from retail stores, and that suggested refrigerator gas leakage as a possible cause. Trials made with butter exposed, in desiccators, to the gas of sulphur dioxide, carbon dioxide, ammonia, methyl chloride, and hydrochloric acid, respectively, showed that sulphur dioxide gas, and also hydrochloric acid gas, turned the butter a pink red, while neither ammonia, nor methyl chloride, nor carbon dioxide gas produced the pink color. It was further demonstrated that in the case of sulphur dioxide gas and hydrochloric acid gas the typical pink coloration was confined to butter containing aniline butter color, such as the U. S. certified "Yellow A B," or "Yellow O B." In the case of June butter, containing no artificial butter color, and of butter containing added vegetable butter color (Annatto color), a very slight pink hue seemed to appear at first, especially along the edges of the butter prints, but upon longer exposure the prints became snow white. In the case of sulphur dioxide gas the coloration was a pure strawberry pink, the yellow color having been bleached by the gas. In the case of hydrochloric acid gas, the color was of a deeper red or orange red, since the natural yellow present in butter had not bleached away.

The experimental results cited above emphasize that the pink butter defect may be expected to result from gas leaks in store refrigerators using sulphur dioxide gas, and that in the case of trouble with pink butter, inspection of the refrigerator of the complaining store, by a competent refrigeration expert, offers the most promising means of prevention. Since contact of butter with all of the refrigerants commonly used in artificial refrigerators, causes severe oxidation, tallowy flavor and bleaching, gas leaks in these refrigerator units, regardless of kind of gas used, are highly objectionable.

Moldy Butter.—Moldy butter is butter that shows visible mold growth. Butter is seldom entirely free from mold cells, even when produced in factories that maintain a high standard of sanitary efficiency. However, it is only under conditions that permit of profuse contamination and that are especially favorable to mold development, that sufficient mold growth occurs for mold spots to appear on or in the butter.

Moldy butter is shunned by the trade and is rated "No score." It is generally accompanied by off-flavors. Its greatest objection, however, lies in its unsightly appearance, and in the loss of butter and cost of labor that are associated with the removal of the moldy portions from such butter.

The tendency for commercial butter to develop mold spots is greatest during the summer months. Moldy butter complaints from wholesale receivers are a seasonal recurrence characteristic of the summer season. The defect usually appears on the surface in the form of mold spots. The color of these spots varies with the species of mold involved. The most common color is a greyish green, though yellowish red and brown-black colorations are frequently also encountered. In aggravated cases, these spots may penetrate the butter to a considerable depth, and the mold filaments may grow to a length that causes the surface to be "bearded." In exceptional cases the interior of the entire mass of butter is infested with spots and arteries of mold.

The genera and species of molds that are capable of growing in butter are numerous. To these belong Penicillium, Trichosporium, Streptothrix, Cladosporium, Oidium, and many others. Griepenberg[91] who examined storage butter, found that most of the molds in butter belong to the genera Penicillium and Trichosporium, and that the species Penicillium crustaceum and Trichosporium-collae were the most common. According to Thom and Shaw,[92] mold growth in butter is of three general types as follows:

1. Orange-yellow (red) areas, with a submerged growth of mycelium. These are attributed to Oidium lactis.

2. Smudged or dirty green areas, either entirely submerged or with some surface growth. These are produced by Alternaria and Cladosporium.

3. Green surface colonies, which are produced by Penicillium, or more rarely Aspergillus, either upon the butter, causing decomposition, or upon the container or wrapper, injuring the appearance.

Requirements for Mold Growth.—Milk, cream, and butter, contain all the nutrients and water necessary to satisfy the food and moisture requirements of molds. Favorable mold food is often further present in the form of the watery extract from

parchments, and the moisture supply is further supplemented by the humidity of the creamery atmosphere.

Molds require air, they perish in the complete absence of air. The moisture-laden air confined between the butter surface and its wrapper, and in the cracks and cavities of loosely packed butter, favor mold growth.

Molds are readily destroyed by heat treatment, such as is used in efficient pasteurization, as demonstrated experimentally by Thom and Ayres,[93] Hood and White,[94] and Macy.[95] These findings are fully supported by commercial experience.

Molds thrive well at ordinary temperatures, their growth is retarded at low temperatures. Macy and Steele[96] showed that at 5° C. (41° F.) growth of some molds in mold-inoculated butter, was checked for two weeks. At —18° C. (zero F.), no growth occurred in inoculated unsalted butter during storage for 20 weeks. The low storage temperature, however, did not prevent mold growth after cold storage, when butter was held under favorable temperature conditions. Even in a restricted air supply (25 inch vacuum), molds were able to grow at favorable temperatures (room temperature), as demonstrated by Macy.[97]

Salt definitely retards mold growth. Butter containing 2.5% or more salt, when properly manufactured and packed, generally does not become moldy. As the salt content decreases, the tendency of mold growth increases, when other conditions are favorable. Unsalted butter supports active mold growth. At ordinary temperature it molds rapidly. Even the usual creamery cold room temperature (40 to 45° F.) does not prevent molding, although it retards development somewhat. The only dependable means of preventing mold growth in commercial unsalted butter lies in keeping the butter at low temperatures (below the freezing point).

High acidity tends to retard mold growth somewhat. Unsalted butter made from properly ripened cream does not become moldy quite as rapidly as the same butter made from cream that is churned sweet.

Prevention of Moldy Butter.—Plate counts of fresh butter made in an efficiently operated plant, with a high standard of sanitation, usually show very few, if any, mold colonies. The major precautions necessary to assure a low plate count on

fresh butter and to retard subsequent mold growth, are listed below:

1. Milk and Cream. It is commercially impossible to prevent the presence of molds in milk and cream at the time of delivery to the creamery.

2. Pasteurization. Efficient pasteurization of the cream will destroy most of the mold cells present in the cream. This is true of pasteurization by the holding process at 145° F. or higher, for 30 minutes, and of the flash process at 180 to 185° F. or higher, if efficiently performed, as explained in Chapter XI on "Pasteurization."

3. Starter. If a starter is used, it should be kept pure and free from contamination. High mold counts are not infrequently traced to contaminated starter.

4. Sanitation of Equipment. All equipment, from pasteurizer to butter cutter needs to be thoroughly washed, rinsed and sterilized at the end of the day's operations, and flushed and sterilized again before use on the following day. Wooden equipment requires special treatment. This refers to churns, butter workers and butter packing and printing equipment. For details see Chapter IV on "Creamery Equipment" and Chapter V on "Creamery Sanitation."

5. Water. Pure water is essential to a low mold count in butter. Stale and polluted water may teem with mold cells. If the only water supply that is available is of uncertain purity, treat the water used for washing wooden equipment, for rinsing down the vat when filling the churn, for washing the butter, and for moisture control work, by filtration, pasteurization or chlorination. See Chapter IV on "Water Supply."

6. Salt. Keep the salt in a clean, dry place. Do not break the seal of barrels or sacks until needed. Keep remnant barrels covered and remnant sacks closed.

7. Packing Supplies. Keep cubes, tubs, parchment liners and wrappers away from dampness. Store them in a clean, dry place, and a pure, dry atmosphere. Keep liners, circles and wrappers sealed in their original package until needed.

8. Preparation of Parchment Liners and Wrappers. Soak all pachments used for salted butter and for bulk unsalted butter for 30 minutes in boiling hot, saturated brine; and for unsalted print butter in boiling hot water. Use new brine for such treat-

ment each day, as the brine once used contains the water-soluble extract of parchment paper, which is rich in food for molds. Where Parchfoil is used, omit treatment.

9. Preparation of Tubs. Properly paraffin, or casein-coat all tubs. Heat them over steam jet until "piping-hot" and use boiling paraffin. Do not nest paraffined tubs, keep them stacked top to top and bottom to bottom until needed.

10. Body of Butter. Work butter to a compact, dry body. A wet, loose, leaky butter facilitates migration of mold spores and penetration of mold filaments.

11. Packing. Pack the butter solidly, avoiding air pockets and cracks. Air in butter favors mold growth.

12. Storage of Butter. Store the packed butter in the creamery cooler at as low a temperature as practicable. Keep the creamery cooler dry, free from rubbish, and the walls and ceilings free from mold.

13. Creamery Ventilation and Sanitation. Keep the creamery well ventilated, and the sewers, floors, walls and ceiling clean. A stagnant, humid and impure atmosphere breeds molds rapidly and constitutes a constant source of mold contamination and a stimulant for mold growth.

14. Impregnation of Parchment Wraps with Propionate. Within recent years the use of parchment wraps impregnated with sodium propionate (NaPr), or calcium propionate ($CaPr_2$) has been recommended as a means of preventing or retarding mold growth on butter. Experiments by Hunziker and Cordes[99] showed a very decided inhibition of mold growth as the result of propionate treatment of the wraps. They used dry parchments already impregnated by the manufacturer, as well as plain parchments which were soaked in different concentrations of sodium or calcium propionate in aqueous solution just before use. The results lacked somewhat in uniformity, but they were sufficiently decisive to leave no doubt as to the ability of propionate treatment to definitely retard mold growth. Similar results were also reported by Macy and Olson.[98]

It was observed, however, by Hunziker and Cordes,[99] that the butter wrapped in treated parchment had a pronounced propionate odor upon opening the package, which may prove objectionable to the trade. This odor was present in the case of the previously impregnated, dry wraps, as well as with the butter

wrapped in freshly soaked, wet wraps. On account of this pronounced odor, caution suggests the wisdom of further tests before the general adoption of propionate-treated parchment wraps is justifiable.

Glass in Butter.—Glass may be incorporated in butter as result of accidental breaking of a glass instrument or container, such as a thermometer, pipette, or beaker. Glass chips in butter are practically invisible, because of their transparent character. Butter with particles of glass in it is a serious menace to both the butter eater and the creamery. It may jeopardize the well-being of the unsuspecting consumer, perhaps causing permanent injury, and it may involve the creamery in costly law suits.

Butter in which particles of glass have been noticed at the plant, or which is suspected of containing glass, should not be allowed to go out to the trade. The only means of rendering such butter safe is to melt it, allow the glass particles to settle out, and after carefully straining the oil, to re-run it with churnings of fresh cream.

Extraneous Matter in Butter.—Extraneous matter in butter refers to the presence in butter of any object, or insoluble material, that is foreign to the composition of normal butter. The presence of foreign matter of whatever nature, in a food product like butter, is highly objectionable. At best it does not belong there, suggests carelessness, and invites justifiable criticism and complaints from the buyer.

There are two major channels through which extraneous matter may become incorporated in the butter; namely, contaminated cream supply and contamination in the factory. The most common foreign matter that may be found in the cream upon its arrival is particles of dust, dirt, feed, bedding, rust from rusty cans, animal hair, parts of insects, etc.

Some of this material is soluble and has gone into solution by the time the cream reaches the factory. It, therefore, cannot be removed by straining. It might be partly removed by reseparation which, however, is economically impractical. A small portion of it, therefore, is inevitably churned into the butter, while the bulk passes off in the buttermilk. Much of the insoluble foreign matter in the cream is of such small particle size that it passes through the finest mesh cream strainers that are suitable for cream. This material is picked up by and becomes

incorporated in the butter. The coarser particles are generally eliminated by the cream strainers provided in the factory.

It is obvious that the surest way of keeping extraneous matter of this origin (the farm) out of the butter is to prevent it from getting into the cream in the first place. Careful grading, rejection of cream containing visible extraneous matter, and timely advice to the producer regarding the status of purity of his cream, accompanied by helpful suggestions for improvement, are bound to lessen the danger of excessive and objectionable extraneous matter in the cream supply. The use of the cream sediment test, showing the farmer the sediment disc resulting from the test on his cream, has proved of tangible help in efforts to convince him of the need of improvement in the sanitary care of the cream on the farm. For sediment tests of cream, see Chapter XXV, on "Factory Tests."

The factory also may, and frequently does constitute a prolific source of extraneous matter in butter. In an efficiently operated plant, with properly instructed and intelligently supervised personnel, this danger is negligible, barring accidents. In factories poorly equipped, insufficiently manned, and lacking in supervision, the tendency of the presence of extraneous matter in butter is ever-present.

The character of foreign matter in such case may involve a great variety of objectionable material, such as: coal dust and soot from boiler room, scale from water and steam pipes, rust from corroding bolt heads in churns, wood splinters from damaged worker rolls, churn shelves and packing equipment, metal specks from grinding pump bearings and ground-up wires from can seals, grit from a roily water supply and from unclean water storage tanks, particles of rubber from delapidated hose and defective churn gaskets, hair from untidy employees in factory and print room, burnt casein particles from unclean heating surfaces, parts of insects in the absence of efficient insect control, etc.

An efficient system of cream strainers of suitable fineness of mesh, in good repair, clean and properly functioning, will do much to minimize the amount of extraneous matter in butter. Such a system should embrace means of straining the cream before the extraneous material has had opportunity to be ground-up in cream pumps or dissolved by heat exposure; of straining the cream after pasteurization to eliminate the possible

presence of coagulated or "burnt" casein particles; of straining at the churn to remove any chance objects that may have reached the cream later; and of filtering the butter wash water into the churn. In short, it means an efficient strainer between forewarmer and pasteurizer, between pasteurizer and holding vat, properly functioning churn strainer, and a fine strainer for the water used for washing the butter.

While the strainer is an important and indispensable part of a properly equipped creamery, it can be at best only a remedy. Dependable prevention of objectionable extraneous matter lies in clean cream and eternal vigilance at every stage of plant operation, to guard against access to cream and butter of material foreign to pure butter. Sediment tests of butter at regular, reasonable intervals, provide valuable information relative to the status of foreign matter in the butter and assist in the gradual elimination of sources of such contamination.

Hotel Complaints on Curd in Oil of Melted Butter.—Hotels and restaurants that are serving melted butter oil on fish and meats, occasionally complain that the butter they are receiving shows too large a proportion of curd, or that the melted oil is not clear, or that the curd is too dark in color. These complaints may become embarrassing to the creamery, jeopardizing its trade with the complaining hotel. The hotel chef usually secures his melted butter oil by melting the butter in a can or pan set in hot water. He aims to heat the oil to about 160-170° F., and he is always "sure" of his temperature, although he uses no thermometer.

It was shown in Chapter XXI, under "The Curd," that the curd content of butter is influenced by certain procedures in manufacture. The working of starter into the butter increases it somewhat and the incorporation of skim milk powder yields butter with an abnormally high curd content. Creameries that use such practices of curd incorporation, therefore, may expect justifiable complaints from buyers who melt their butter.

It was further shown in Chapter XXI that butter made by normal methods of manufacture, and in the absence of practices that are intended to increase the curd content, averages a curd content of approximately 0.7 to 0.8%, and that this curd content is fairly uniform. In fact, differences in per cent curd by weight of normally made butter coming from different cream-

eries are largely negligible. If such butter brings complaints on excessive curd, therefore, the creamery may be reasonably certain that the fault does not lie in the composition of its butter, but has to do with factors controlled by the user, such as manner of melting the butter, or perhaps competitor propaganda, or price-reducing efforts.

Hotels and restaurants are not interested in the percentage of curd by weight. They are judging the curd content by the apparent, visible volume of curd that settles out from the melted butter oil. Aside from the percent curd by weight, the volume of settled-out curd is materially influenced by the temperature at which the butter is melted. High melting temperatures tend to contract the particles of curd, causing them to deposit in the form of a compact mass of relatively small volume. Low melting temperatures tend to preserve the flocculent character of the curd, causing it to form a less compact and relatively large volume of deposit.

Honest complaints on excessive curd in butter made by normal methods of manufacture, therefore, suggest the probability that the butter in question was melted at a lower than the customary temperature. A practical demonstration in the presence of the chef is usually the most effective means of convincing him of the facts. This is readily done by the use of two glass cylinders. Melt a sample of the creamery's butter and a sample of butter which the chef claims to show normal curd content, at the same temperature, by setting both samples in the same water bath at say 170° F. and hold them there for the same length of time. Then pour the hot melted butter of each sample into the two glass cylinders and allow the curd to settle out.

The results almost invariably show no appreciable difference in the depth of the layer of curdy material between the two samples. In general, there is a tendency for sweet cream butter to yield a slightly looser and larger curd deposit than butter from sour, neutralized cream.

The color of the curd and the clearness of the liquid immediately above the curd layer are influenced somewhat by the character of the butter. Sweet cream butter yields a light colored, creamy-whitish curd and a fairly clear whey. Sour, neutralized cream butter, especially in the case of very high acid cream, yields a darker colored, more or less grayish-brown curd and a

less clear whey. The darkening of the curd appears to occur regardless of kind of neutralizer used, but tends to be somewhat more pronounced with soda than with lime neutralizer.

REFERENCES

1. BABCOCK, C. J., U. S. Dept. Agr. Bul. 1190, (1923).
2. ROADHOUSE, C. L., and HENDERSON, J. L., Cal. Agr. Expt. Sta. Bul. 595, (1935).
3. DICE, J. R., N. D. Agr. Expt. Sta. Bul. 194, (1926).
4. RIDDET, W., LEVY, E. B., WOODCOCK, J. W., MARRYAT, E. R., Hodgson, J. N., and SEARS, P. D., N. Z. Dairy Res. Instit. Publ. 84, (1937).
5. McDONALD, M. B., and GLASER, A., Tenn. Agr. Expt. Sta. Circ. 26, (1929).
6. WEIGMANN, H., Die Mykologie der Milch 210, (1911).
7. HUNZIKER, O. F., and PITZ, W., Blue Valley Res. Lab. (not publ.), (1920-1922).
8. HAMMER, B. W., and CORDES, W. A., Ia. Agr. Expt. Sta. Res. Bul. 61, (1920).
9. ORLA-JENSEN, S., Die Bakteriologie in der Milchwirtschaft, (1913).
10. HARRISON, F. C., Landw. Jahrb. d. Schweiz 14, (1900).
11. SPITZER, GEO., and EPPLE, W. F., J. D. Sc. III, *6*, (1920).
12. HUNZIKER, O. F., and CORDES, W. A., Blue Valley Factory, Hastings, Nebr., (1927).
13. GUTHRIE, E. S., N. Y. (Cornell) Agr. Expt. Sta. Bul. 373, (1926).
14. CORDES, W. A., Blue Valley Res. Labs. (not publ.), (1926).
15. HUNZIKER, O. F., Addr. Am. Butter Inst. 28, (1937).
16. GILRUTH, J. A., N. Z. Dept. Agr. 7th Rept., (1899).
17. ORLA-JENSEN, S., Cited by Hood and White, see (20).
18. SADLER, W., and VOLLUM, R. L., Can. Nat. Res. Council Rept. 16, (1926).
19. HUNZIKER, O. F., and CORDES, W. A., Blue Valley Res. Labs. (not publ.), (1922-39).
20. HOOD, E. G., and WHITE, A. H., Can. Dept. Agr. Pamphl. 91 N. S., (1928).
21. MACY, H., by Correspondence and Interview, (1925).
22. SHUTT, D. B., Butter, Cheese and Egg Jour. 22, July, (1929).
23. BROWN, A. M., Agr. Gazette, N. S. W. *39*, 843, (1928).
24. DERBY, H. A., and HAMMER, B. W., Ia. Agr. Expt. Sta. Res. Bul. 145, (1931).
25. LEA, C. H., Rancidity in Edible Fats, 50, (1939).
26. MACY, H., Am. Cry. and Poultry Prod. Rev. 802, March 9, (1932).
27. HERREID, E. O., MACY, H., and COMBS, W. B., Minn. Agr. Expt. Sta. Tech. Bul. 97, (1934).
28. HAMMER, B. W., Dairy Bacteriology, 2nd ed., (1938).
29. ORLA-JENSEN, S., Landw. Jahrb. d. Schweiz, (1901).
30. KIRCHNER, W., Berichte d. Deutsch. Bot. Gesell. 101, (1888).
31. BROWNE, C. A., J. Am. Chem. Soc. *21*, (1928)
32. HAMMER, B. H., and COLLINS, M. A., Ia. Agr. Expt. Sta. Res. Bul. 169, (1934).
33. LEWKOWITSCH, J., Chem. Tech. and Anal. of Oils, Fats and Waxes, I, (1913).
34. HUNZIKER, O. F., and HOSMAN, D. FAY, J. D. Sc. I, *4*, 320, (1917)
35. KING, N., Zeitschr. f. Milchunde u. Milchw. XII, 1 & 2, 172 (1931).
36. TRACY, P. H., and RAMSEY, R. J., Ill. Agr. Expt. Sta. Bul. 389, (1933).
37. ROGERS, L. A., Third Intern. Cong. Refrig., Washington-Chicago, (1913).
38. DYER, D. C., J. Agr. Res. VI, *24*, 927, (1916).
39. HARDING, H. A., ROGERS, L. A., and SMITH, G. A., N. Y. (Geneva) Agr. Expt. Sta. Bul. 183, (1900).

40. LEWKOWITSCH, J., Chem. Tech. and Anal. of Oils, Fats and Waxes II 798, (1914).
41. SOMMERFELD, P., Handbuch d. Milchkunde, (1909).
42. PLATON, B., and OLSSON, T., Swed. D. Expt. Sta. Bul. 467, (1936).
43. RITTER, W., Schweiz. Milch Ztg., 95-98, (1936).
44. PIFFARD, H. G., N. Y. Prod. Rev. & Am. Cry. *13*, 2, 20, (1902).
45. CALLAGHAN, M. A., Agr. Gazette, N. S. W., *18*, 223, (1907).
46. CALLAGHAN, M. A., Agr. Gazette, N. S. W., *12*, 341, (1901).
47. CALLAGHAN, M. A., Chic. D. Prod. *8*, Apr. 25, (1916).
48. DAVIES, W. L., The Chemistry of Milk, (1939).
49. HARRISON, F. C., 27th Ann. Rept. Ont. Agr. Expt. Sta. 79, (1901).
50. KLEIN, J., Milchwirtschaft, 238, (1914).
51. HAMMER, B. W., Ia. Agr. Expt. Sta. Res. Bul. 38, (1917).
52. SOMMER, H. H., Proc. World Dairy Cong. 2, (1923).
53. STORCH, V., Milch Ztg. 304, (1906).
54. ROGERS, L. A., U. S. Dept. Agr. B. A. I. Circ. 146, (1909).
55. ROGERS, L. A., U. S. Dept. Agr. B. A. I. Bul. 57, (1904).
56. ROGERS, L. A., and GRAY, C. E., U. S. Dept. Agr. B. A. I. Bul. 114, (1909).
57. ROGERS, L. A., THOMPSON, S. C., and KIETHLEY, J. R., U. S. Dept. Agr. B. A. I. Bul. 148, (1912).
58. SUPPLEE, G. C., N. Y. (Cornell) Agr. Expt. Sta. Mem. 29, (1919).
59. CUSICK, J. T., N. Y. (Cornell) Agr. Expt. Sta. Mem. 30, (1920).
60. SOMMER, H. H., and SMIT, B. J., Wis. Agr. Expt. Sta. Res. Bul. 57, (1923).
61. VAN DAM, W., Proc. World Dairy Cong. *2*, 1004, (1923).
62. ARUP, P., Analyst *53*, 641, (1928).
63. QUAGLIARIELLO, G., Abstr. Milchw. Forsch. *7*, 31, (1929).
64. KING, N., Kolloid Zeitschr. I-II, *3*, 319, (1930).
65. VAN DAM, W., and BURGERS, W. G., J. D. Sc. XVIII, *1*, 45, (1935).
66. HAGLUND, E., WODE, G. and OLSSON, T., Centralanst. Försoksv. Jordbruksomradet. Meddel, 387, (1930).
67. WODE, G., Centralanst. Försoksv. Jordbruksomradet. Meddel. 438, (1933).
68. STORGARD, Cited by Coulter and Combs, see (70).
69. MOHR, W., and OLDENBURG, F., Molk. Ztg. Hildesheim IIL, *23*, 378, (1934).
70. COULTER, S. T., and COMBS, W. B., Minn. Agr. Expt. Sta. Tech. Bul. 115, (1936).
71. WILSTER, G. H., STEIN, R. W., and STOUT, R. E., J. D. Sc. XXII, *6*, 425, (1939).
72. RICHARDSON, G. A., and ABBOTT, F. H., 21st Ann. Meetg. West. Div. Am. Dairy Sci. Ass., Portland, Ore., (1935).
73. HUNZIKER, O. F., Blue Valley Cry. Co., Chicago, (1936-39).
74. STOUT, R. E., Ore. Agr. Expt. Sta. Progr. Rept. Proj. XXI, (1938).
75. HUNZIKER, O. F., MILLS, H. C., and SPITZER, GEO., Purdue Agr. Expt. Sta. Bul. 160, (1912).
76. DAHLBERG, A. C., J. D. Sc. V. *5*, 421, (1922).
77. KUHLMAN, A. H., and GALLUP, W. D., J. D. Sc. XXII, *6*, 424, (1939).
78. KEITH, J. I., KUHLMAN, A. H., WEAVER, E., and GALLUP, W. D., J. D. Sc. XVIII, *7*, 469, (1935).
79. HUNZIKER, O. F., Blue Valley Factory, Dardanelle, Ark., (1930).
80. HUNZIKER, O. F., Blue Valley Factory, Parsons, Kans. (1917).
81. PALMER, L. S., and ECKLES, C. H., J. Biol. Chem. *17*, (1914).
82. PALMER, L. S., Mo. Agr. Expt. Sta. Circ. 74, (1915).
83. HUNZIKER, O. F., and CORDES, W. A., Blue Valley Res. Labs. (not publ.), (1931).
84. STORCH, V., Milch Zeitung, (1897).
85. SAMMIS, J. L., and LEE, C. E., Wis. Agr. Expt. Sta. 29th Ann. Rept. (1912).
86. HUNZIKER, O. F., and HOSMAN, D. FAY, J. D. Sc. III, *2*, 77, (1920).
87. BOYSEN, H., Inaug. Diss. Kiel, (1926).

88. HUNZIKER, O. F., and HOSMAN, D. FAY, J. D. Sc. I, *4*, (1917).
89. RAMSAY, A. A., BROWN, A. M., and RANDELL, H. H., The World's Butter Rev. *6*, (1927).
90. HUNZIKER, O. F., CORDES, W. A., and NISSEN, B. H., Blue Valley Res. Lab. (not publ.), (1930).
91. GRIEPENBERG, Cited by Fleischmann, Lehrbuch d. Milchwirtschaft, (1915).
92. THOM, C., and SHAW, R. H., J. Agr. Res. III, *4*, (1915).
93. THOM, C., and AYRES, S. H., J. Agr. Res. VI, *4*, (1916).
94. HOOD, E. G., and WHITE, A. H., Can. Dept. Agr. D. D. R. Bul. 48, (1925).
95. MACY, H., Rept. Insp. Blue Valley Factory, Sauk Centre, Minn. (1926).
96. MACY, H., and STEELE, G. H., J. D. Sc. XVII, *5*, 397, (1934).
97. MACY, H., Minn. Agr. Expt. Sta. Tech. Bul. 64, (1929).
98. MACY, H., and OLSON, J. C., J. D. Sc. XXII, *7*, 527, (1939).
99. HUNZIKER, O. F., and CORDES, W. A., Blue Valley Res. Labs. (not publ.), (1938).
100. KEITH, J. I., RINK, C. W., and KUHLMAN, A. H., J. D. Sc. XX, *7*, 462, (1937).
101. 22nd Report Danish Expt. Sta. Hillerod, Denmark, (1939).

PART VI

Factory Control of Composition and Quality

CHAPTER XXIV

BUTTER SCORING, STANDARDIZING MILK AND CREAM—DEFINITIONS AND STANDARDS

1. BUTTER SCORING

Purpose and Importance.—By butter scoring is understood the examination of butter for flavor and aroma, body and texture, color, salt and package.

The primary object of scoring butter is that of determining its quality and market value. Butter that is sold under the "call" is scored by the official inspector of the Mercantile Exchange. Butter that goes direct to the wholesaler, jobber, or commission man, is usually sold "over the trier," that is, it is scored by the buyer and purchased on the basis of the score he gives it. In the case of butter intended for cold storage special emphasis is placed on those characteristics that suggest or relate to keeping quality.

The importance of butter scoring by the buyer is obvious. He must know the quality of what he buys before the purchase is made. The practice of scoring butter by the buttermaker is no less important. The alert buttermaker will want to know the quality of the butter he is making. It is good practice for him each day to score the butter of the previous day. He thus is in a position to detect any defect in flavor, body and color, and to adjust the grading of cream and method of manufacture so as to promptly avoid recurrence.

The grading standards and score cards on the basis of which butter is scored in the United States are given in Chapter XIX on "Markets and Marketing," under "Grades and Standards for Quality of Butter."

Accuracy of Score Depends on Qualifications of Butter

Judge.—The fundamentals of accurate scoring of butter have to do primarily with the qualifications of the individual doing the scoring. He must be sufficiently interested in butter to like the work and to preclude the tendency of looking upon the tasting of butter as a distasteful task. Most persons have a sufficiently keen sense of taste to enable them to distinguish between desirable flavor and objectionable flavor. The finer distinctions of flavor between market grades come with practice and experience. Taking advantage of every opportunity to accompany butter judges at National and State butter exhibits, etc., is usually of much assistance in efforts to learn how to put the correct score on butter. The following timely advice by Mr. P. H. Kieffer,[1] President of Gude Bros. Kieffer Co., merits special attention:

"A buttermaker should have a starting point in scoring butter, and I believe 93 score butter is the starting point, because that is butter that is clean in flavor and taste. After having the 93 score once established in his mind it is easy then to place the 92. Ninety-two scoring butter is butter termed extras and that will score just under 93 due to the fact that it may be a trifle coarse in flavor or show some other minor defects, but in no case can it have a pronounced old cream or poor milk flavor. Then the next score to become familiar with is the 90 scoring butter and then become familiar with the 88. After he has once in his mind, well placed, 93, 92, 90 and 88 scoring butter, he will find it an easy matter, with care and good judgment, to place the scores on butter scoring between any of the above scores or higher than 93 and lower than 88 score.

"If a buttermaker can accompany a judge for four or six days and at the same time concentrate on each package that is being scored, it will give him quite an insight into scoring and by repeating this as often as he can he will soon commence to note progress."

Equipment for Scoring.—The proper procedure of scoring butter is materially facilitated by the availability of suitable tools. These consist of a standard butter trier, kept satisfactorily plated (plating with nickel, chromium, tin or silver is suitable), a knife or spatula, and a supply of clean cloth or soft paper, such as cheese cloth or paper toweling. This equipment should be available in every creamery. A trier handy at all times is more inducement to the busy buttermaker to sys-

tematically score his butter, than when he has to resort to miscellaneous tools such as a knife, stick, or pencil, with which to scrape a sample off the package.

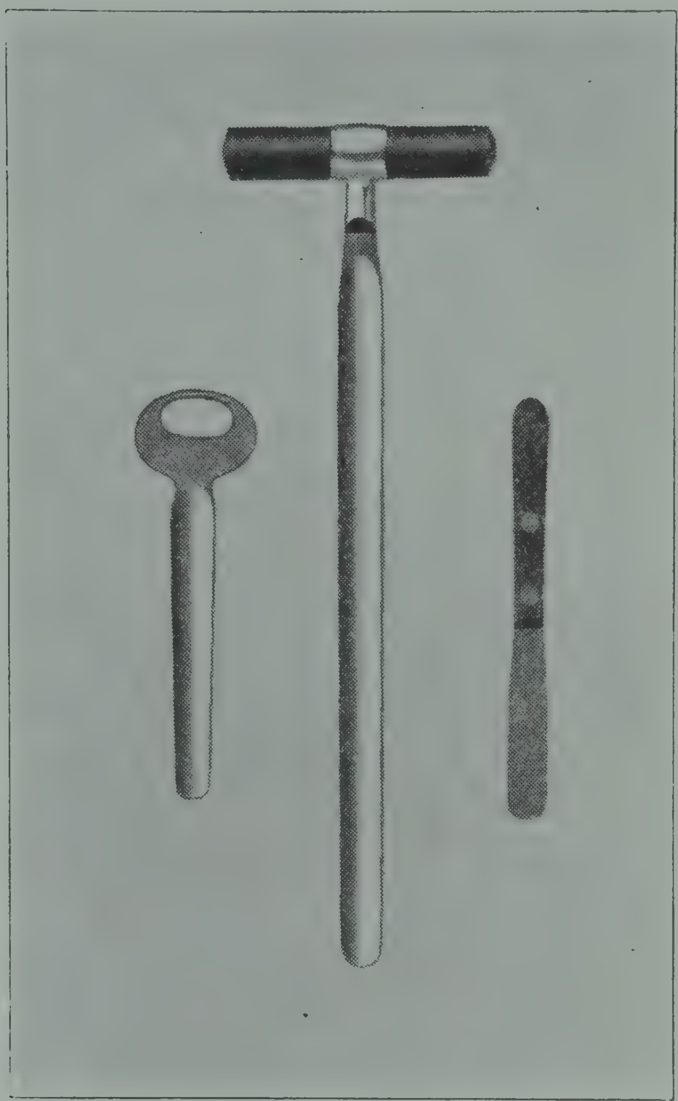


Fig. 120. Suitable tools for butter scoring

Method of Scoring.—The scoring of butter should be done with clean hands and in an atmosphere free from odors of any kind. Before drawing a plug the trier should be wiped clean. The trier is then placed near the center of the package, given half a turn and a plug is drawn. It is then brought directly to the nose to get the full effect of the aroma. A segment is then cut off the plug with the spatula and placed into the mouth to

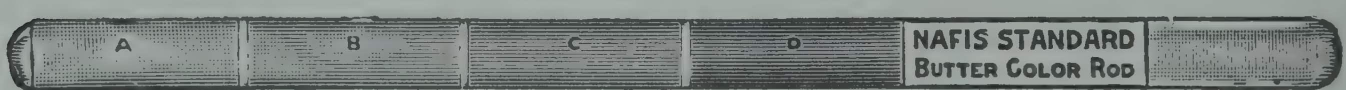


Fig. 121. Standard butter color rod
Courtesy of Kimble Glass Co.

determine the flavor. The concentration of salt (saltiness) is also noted at this stage. The plug is examined to note the color, body and texture. Special attention is paid to presence or absence of free moisture, and of mottles and waves. The plug is

given a slight pressure with the thumb to note the grain, and the back of the trier is examined for tendency to stickiness, and to see if the butter had received the proper workmanship. After examination, the plug is neatly returned to the bore and the surface smoothed over with trier or spatula.

Scoring Experimental and Contest-Butter.—Efficient butter scoring requires concentration by the judge on the examination of each package. Conversation by others present hinders such concentration. When more than one judge does the scoring, as is generally the case at educational or national butter exhibits, also when scoring experimental butters, each judge should work entirely independent of the other judges. There should be no expression of opinion, nor comparison of notes between judges, until each judge has completed his work and recorded his results. At the conclusion of the scoring, notes may be compared and packages on which the judges' scores differ, may be rescored. The average of the individual scores of the several judges thus represents the sum of the individual judgment of each judge and promises maximum dependability of the accuracy of the final score awarded to each package.

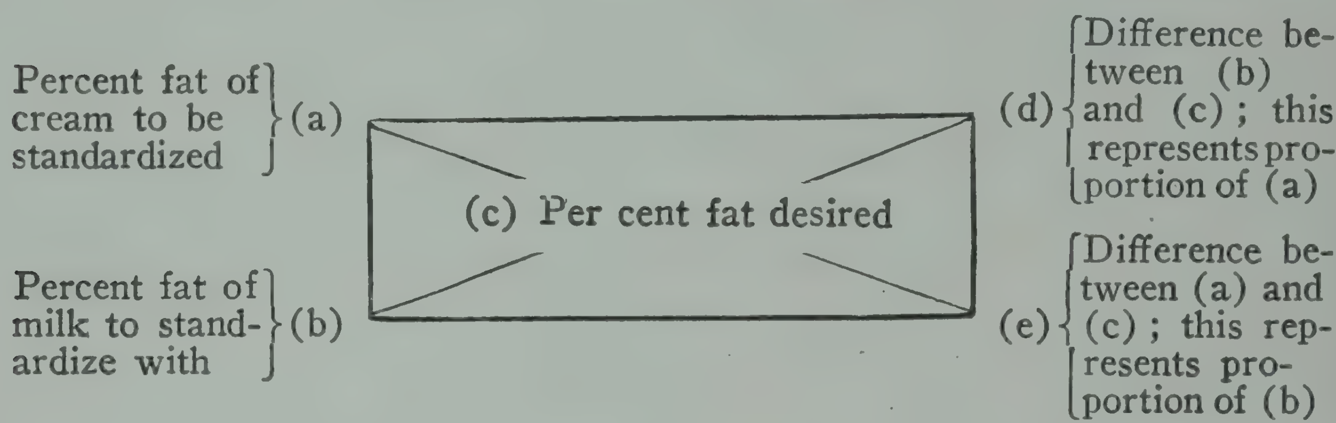
2. STANDARDIZING MILK AND CREAM

In the operation of the creamery it frequently becomes desirable, and sometimes necessary, to standardize milk or cream of any richness to a definite per cent of fat.

Usual Information Needed for Accurate Standardization.—The standardization may require the utilization of a definite amount of milk or cream on hand, or the production of a definite volume of standardized product. In some cases the product with which to standardize may be on hand ready for use. When not available, a portion of the cream or skim milk may have to be removed by separation. In such case it is advantageous to know how much of the milk that is available must be separated to standardize the remainder to the proper per cent of fat, when the resulting skim milk or cream is returned to the unseparated portion of the milk, or when a definite amount of cream of specific fat content is desired.

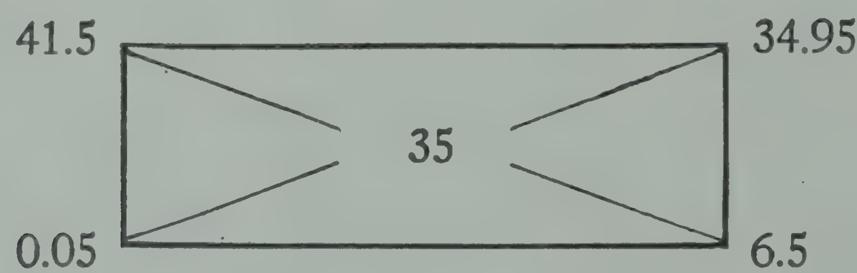
Simplified Calculations for Standardization.—Calculations for such standardization are generally simplified by the use of the Pearson square. The square operates as follows: Place the

per cent of fat desired in the center of the square. In the upper and lower left hand corners, place the percentages of fat of the milk and cream available for standardization. In the upper right hand corner place the difference between the figure in the center and the figure in the lower left hand corner. In the lower right hand corner place the difference between the figure in the center and the figure in the upper left hand corner. The figures in the upper and lower right hand corners thus represent the correct proportion in which the two liquids must be mixed. The figure in the upper right hand corner refers to the liquid recorded in the upper left hand corner, the figure in the lower right corner refers to the liquid in the lower left hand corner. The following examples may serve to illustrate the method:



EXAMPLE 1.

800 lbs. of 41.5% cream must be reduced to 35% cream by the use of skim milk testing 0.05% fat. How much skim milk must be added:



34.95 : 6.5 = 800 : X; X = 148.78 lbs. skim milk that must be added to the 800 lbs. of 41.5% cream to produce 35% cream.

Proof:

800 lbs. 41.5% cream contains $800 \times \frac{41.5}{100} = 332$ lbs. fat

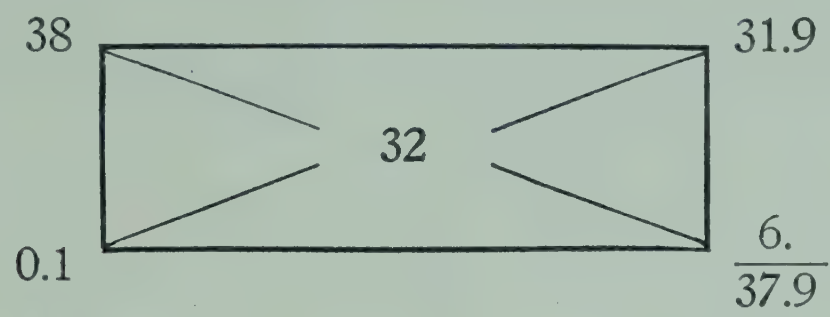
148.78 lbs. 0.05% skim contains $148.78 \times \frac{0.05}{100} = 0.07439$ lbs. fat

948.78 lbs. standardized cream contains 332.07439 lbs. fat

Per cent fat in standardized cream $= \frac{332.07439}{948.78} \times 100 = 35\%$

EXAMPLE 2.

2000 lbs. of 32% cream are wanted. 38% cream and skim milk containing 0.1% fat are available. How many pounds of 38% cream and of skim milk are needed?



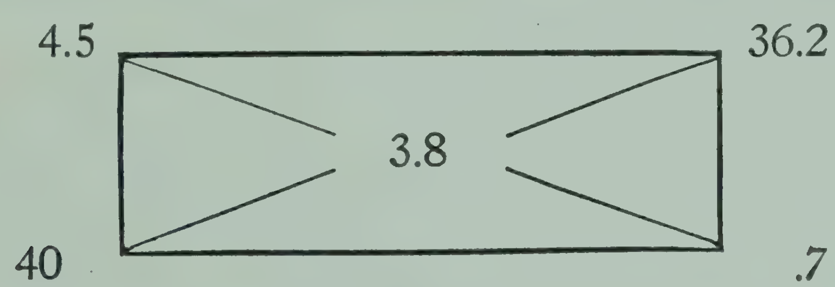
37.9 : 31.9 = 2000 : X ; X = 1683.4 lbs. 38% cream required
37.9 : 6 = 2000 : X ; X = 316.6 lbs. 0.1% skim milk required

Proof:

1683.4 lbs. 38% cream contains	$1683.4 \times \frac{38}{100}$	= 639.69 lbs. fat
316.6 lbs. 0.1% skim contains	$316.6 \times \frac{0.1}{100}$	= .31 lbs. fat
2000 lbs. standardized cream contains		= 640 lbs. fat
Per cent fat in standardized cream	$\frac{640}{2000} \times 100$	= 32%

EXAMPLE 3.

100 lbs. of 4.5% milk must be reduced to 3.8% milk by separation. How much 40% cream must be removed by skimming, returning the skim milk to the remaining whole milk?



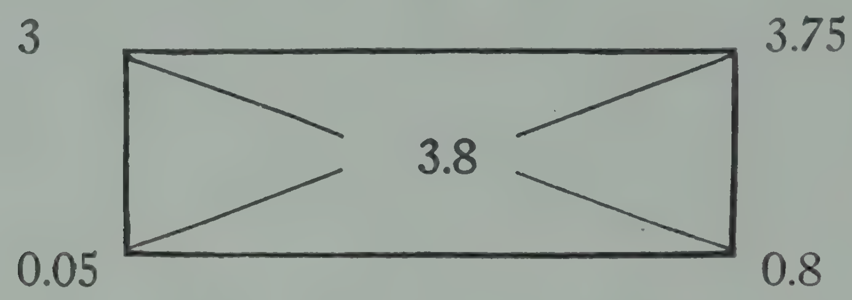
36.2 : .7 = 1000 : X; X = 19.33 lbs. of 40% cream that must be removed.

Proof:

1000 lbs. 4.5% milk contains	$1000 \times \frac{4.5}{100}$	= 45 lbs. fat
19.33 lbs. 40% cream contains	$19.33 \times \frac{40}{100}$	= 7.732 lbs. fat
980.67 lbs. standardized milk contains		= 37.268 lbs. fat
Per cent fat in standardized milk	$\frac{37.268}{980.67} \times 100$	= 3.8%

EXAMPLE 4.

5,000 lbs. of 3% milk must be standardized to make 3.8%. The skim milk tests 0.05% fat. How much skim milk must be removed, returning the cream to the remaining whole milk?



3.75 : 0.8 = 5,000 : X; X = 1066.67 lbs. skim milk that must be removed.

Proof:

5,000 lbs. 3% milk contain $5{,}000 \times \frac{3}{100} = 150$ lbs. fat

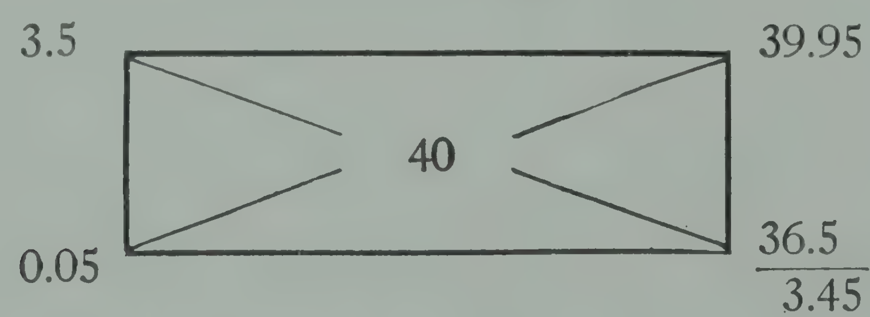
1,066.67 lbs. skim milk contain $1{,}066.67 \times \frac{0.05}{100} = 0.53$ lbs. fat

3,933.33 lbs. of standardized milk contain $= 149.47$ lbs. fat

Per cent fat in standardized milk $\frac{149.47}{3{,}933.33} \times 100 = 3.8\%$

EXAMPLE 5.

How much 3.5% milk must be separated to produce 1,000 lbs. 40% cream, the skim milk testing 0.05% fat?



3.45 : 39.95 = 1,000 : X; X = 11,579.71 lbs. 3.5% milk to be separated to produce 1,000 lbs. of 40% cream.

Proof:

3.45 : 36.5 = 1,000 : X; X = 10,579.71 lbs. 0.05% skim milk produced

11,579.71 — 10,579.71 = 1,000 lbs. of cream produced

11,579.71 lbs. 3.5% milk contains $\frac{3.5}{100} \times 11{,}579.71 = 405.29$ lbs. fat

10,579.71 lbs. 0.05% skim milk contains $\frac{0.05}{100} \times 10{,}579.71 = 5.29$ lbs. fat

1,000 lbs. cream contains 400.00 lbs. fat

Per cent fat of cream $\frac{400}{1{,}000} \times 100 = 40\%$ fat

3. DEFINITIONS AND STANDARDS

Butter Standards.—The standards for the composition of butter are limited principally to specifications of minimum percentage of fat required, or maximum percentage of moisture permitted, or both. While they vary somewhat between different countries, the predominating minimum fat limit is 80% and the maximum moisture limit is 16%. In some countries distinction is made between salted and unsalted butter and between domestic and export butter. In a few instances the maximum percentage of salt and of non-fat milk solids (curd) by difference are specified. In a few cases the limited use of preservatives in butter is permissible.

Butter Definitions and Standards in the United States.—Butter sold in the United States is subject to two Federal Standards, namely one for maximum percentage of moisture permissible, and one for minimum percentage of fat required.

The Moisture Standard.—The maximum percentage of moisture which butter may contain is defined by Act of Congress of May 9, 1902, defining Adulterated butter as follows:

"That adulterated butter is hereby defined to mean a grade of butter produced, by mixing, reworking, rechurning in milk or cream, refining or in any way producing a uniform, purified or improved product from different lots or parcels of melted or unmelted butter or butter fat, in which any acid, alkali, chemical, or any substance whatever is introduced or used for the purpose or with the effect of deodorizing or removing therefrom rancidity, or any butter or butter fat with which there is mixed any substance foreign to butter as herein defined, with intent or effect of cheapening in cost the product, or any butter in the manufacture or manipulation of which any process or material is used with intent or effect of causing the absorption of abnormal quantities of water, milk or cream; that 'process butter' or 'renovated butter' is hereby defined to mean butter which has been subjected to any process by which it is melted, clarified, or refined and made to resemble genuine butter, always excepting 'adulterated butter' as defined by this act."

In defining adulterated butter as distinguished from butter, the Internal Revenue Department made the following ruling:

"The definition of adulterated butter as contained in the Act of May 9, 1902, embraces butter in the manufacture of which any process or material is used whereby the product is made to contain abnormal quantities of water, milk or cream, but the normal content of moisture permissible is not fixed by the act. This being the case it becomes necessary to adopt a standard for moisture in butter, which shall in effect represent the normal quantity. It is therefore held that butter having 16% or more of moisture, contains an abnormal quantity and is classed as adulterated butter."

The adulterated butter law, enforced by the Internal Revenue Department, applies to "Intra-State" butter, as well as to "Inter-State" butter. This law is now in force, but the enforcement of the 16% moisture ruling has been suspended since the enactment of the 80% fat standard, March 4, 1923.

The Fat Standard.—The minimum percentage of butter fat required in butter was established by Act of Congress, March 4, 1923, which defines butter as follows:

"That for the purpose of the Food and Drug Act of June 30, 1906, 'butter' shall be understood to mean the food product usually known as butter, and which is made exclusively from milk or cream, or both, with or without common salt, and with or without additional coloring matter, and containing not less than 80 per centum by weight of milk fat, all tolerances having been allowed for."

The 80% fat standard is enforced by the Federal Food and Drug Administration. It applies to "Inter-State" butter only. This law is now (1940) in force.

State Standards of Butter.—Most of the states have definitions and standards for butter, which have been enacted into the laws of the respective states. Their enforcement serves to regulate the composition of butter sold intra-state. The legal minimum fat limit in most of the states is in agreement with the Federal standard of 80%. Many of the states still have, in addition, a maximum moisture limit. The enforcement of the state moisture limit has been suspended in most states. This is a move in the right direction, since the efficient enforcement of the minimum fat limit insures full food value to the

Table 78½. Standards of Composition of Butter in Different Countries

In Force in 1940*

Country	Moisture (Maximum) %	Fat (Minimum) %	Country	Moisture (Maximum) %	Fat (Minimum) %
Australia	16	82 (a)	Netherlands	....	80
Belgium	16.5	82	New Zealand	16	80
Brazil	....	80	Norway	16	....
Canada	16	80	Sweden	16	....
Denmark	16	80	Switzerland	....	83 (d)
Germany	16	80 (b)	Union of So. Africa	16	....
Great Britain	16 (c)	....	United States	....	80
Italy	....	82			

By correspondence with respective countries or their American Consulates 1939-40.
(a) Butter made for export to England to contain not more than 16% moisture nor less than 80% fat.
(b) Unsalted butter may contain maximum of 18% moisture.
(c) Milk-blended butter may contain not to exceed 24% moisture.
(d) Cooking butter must contain not less than 82% fat.

consumer, and the single fat standard simplifies the problem of making butter that complies with State and Federal requirements, for the industry. The legal standards for all dairy products by States are given in Table 79.

Renovated Butter, Definition, Standard and Law.—Renovated butter is defined by Act of Congress, approved May 9, 1902, as follows[1]:

"Sec. 4....'Process Butter,' and 'Renovated Butter' is hereby defined to mean butter which has been subjected to any process by which it is melted, clarified or refined and made to resemble genuine butter, always excepting adulterated butter as defined by this Act."

The following explanation of the definition and law on adulterated butter, offered by the Department of Agriculture,[2] may serve as a guidance in the interpretation of the renovated butter law, as above defined:

"(f) 'But if, in such process, or in any (other) way,' 'any acid, alkali, chemical, or any substance whatever is introduced' or used, or if 'there is mixed (therewith) any substance foreign

[1]Revised Regulations Concerning Oleomargarine, also Adulterated Butter and Process or Renovated Butter. U. S. Internal Revenue Dept. Reg. No. 9, Revised July 1907.
[2]U. S. Dept. Agr., B. A. I. Order No. 127, 1904.

Table 79.—Legal Standards for Dairy Products by States*

	Milk			Skim Milk	Cream	Butter		Sweetened Condensed Milk		Unsweetened Evaporated Milk		Plain Ice Cream		Fruit or Nut Ice Cream		Whole Milk Cheese			Skim Milk Cheese		
	Butter Fat %	Solids Not Fat %	Total Solids %	Total Solids %	Butter Fat %	Butter Fat %	Water %	Butter Fat %	Total Milk Solids %	Butter Fat %	Total Solids %	Butter Fat %	Total Milk Solids %	Butter Fat %	Total Milk Solids %	(a) Butter Fat %	Total Solids %	Water %	Butter Fat %	Total Solids %	Water %
U. S. Federal	[1]	[1]	[1]	[1]	18[2]	80		8		7.8[3]	25.5[3]					50		39			
Alabama[4]	3.25	8.5	11.75		18	80	16					10	33	8	33	30.5	61	39			
Arizona	3.25	8.5	11.75	[1]	18	80	16	8	28	7.8[3]	25.5[3]	10	30	8	30	50		39	[5]		
Arkansas[6]												8	32	6	32						
California	3.3	8.5		8.8	20	80		8	28	7.8	25.5	10[7]	[7]	8[7]	[7]	50		[8]	[9]		
Colorado[4]	3.2				18	80		7.7	28	7.7		12		10		50					
Connecticut	3.25	8.5	11.75		[10]	80	16	8	28	7.8	25.5	10[11]	18[11]	8[11]	14[11]						
Delaware	3.25	8.5	11.75		18			8		7.8[3]	33.7[3]	12		10							
District of Columbia	3.5		11.5	9	20	80						8		8							
Florida	3.25	8.5			18	80		8	28	7.8	25.5	10		8		50					
Georgia	3.25	8.5	11.75	9.25	18	80		8	28	7.8[3]	25.5[3]	10		8		50[12]	[12]	39[12]	12		
Idaho[13]	3.2	8	11	9.3	18	80			28	7.8	25.5	10[11]	18[11]	8[11]	14[11]	30			15		
Illinois	3	8.5	11.5	9.25	18	80		8	28	7.8[3]	25.5[3]	12		10		50[14]		39[14]	[15]		
Indiana	3.25	8.5	11.75	8.8	18	80		8	28	7.8	25.5	10	20	8	18	50		39	[1]		
Iowa	3	8.5	11.5	[16]	16	80		8	28	7.8	25.5	12[17]	[17]	10[17]	[17]	30			Less than 30		
Kansas	3.25				18	80		8	28	7.8	25.5	10	20	10	20	50			[19]		
Kentucky	3.25	8		[1]	18	80	16	8	28	7.8	25.5	10	18[18]	10	18[18]	50		39			
Louisiana	3.25	8.5		8	18	80		8	28	7.8	25.5	10[20]	20[20]	8	18	30			Less than 30		
Maine	3.25	8.5	11.75		18				26.5		26.5	14		12		50					
Maryland	3.5		12.5	[21]	18	80		[22]	[22]	[22]	[22]	12	20	8 to 10	15	50					
Massachusetts	3.35		12	9.3	16[23]	80		8	28	7.8	25.5	10	18.5	8	16.5	50					
Michigan	3	8.5	[24]	[25]	18[26]	80	16	8	28	7.8[3]	25.5[3]	12	[27]	10	[27]	50		Max. 40	[29]		
Minnesota	3.25				20	80	16	8	28	7.8	25.5	12		10		50		39			
Mississippi	3	8.5	11.75	8.5	18	80		8	28	7.8	33.7	10		8		50		39			
Missouri	3.25	8.5		9.25	18	82.5		8	28	7.8	25.5	8		8		50[28]			[29]		
Montana	3.25	8.5	11.75	9.9	20	80		8	28	7.8	25.5	10	33	9	33	50		39			
Nebraska	3			9.25	18	80						14		12		50		38			
Nevada	3.25	8.5	11.75		22	80		8	28	7.8	25.5	14		12		50					
New Hampshire	3.35		11.85	8.5	18	80	16	8	28	7.8[3]	25.5[3]	14		12		50		39	[1]		
New Jersey	3		11.5		16	80	16	8	28	7.8	25.5	10		8		50					
New Mexico	3.25	8.5	11.75		18	80	16	8	28	7.8[3]	25.5[3]	12	20	10	20	50					
New York	3		11.5	8.5	[30]	80		8	28	7.8	25.5	10	18[31]	8	[31]	50[32]		40	[33]		
North Carolina	3.25	8.5	11.75	[1]	[34]	80	16	8	28	7.8	25.5	10		F. 8 N. 10		50					
North Dakota	3		12	[1]		80	16	8	28	7.8[3]	25.5[3]	12		10		50		39			
Ohio	3		12	[1]	18[26]	80		[32]				10[17]	18	8[17]	14	[35]			[35]		
Oklahoma	3.5	8.5	12		18	80	16	[36]		[36]		12	32.5	10							
Oregon	3.2	8.5	11.7		18	80				7.8	25.5	12[37]	20	10	18	50					
Pennsylvania	3.25		12	[38]	18	80	16	8	28	7.8[3]	25.5[3]	10	[40]	8	[40]	[39]			[41]		
Rhode Island	3.25		12		18	80		8	28	7.8[3]	25.5[3]	8		8		50		39	[1]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								10	18[7]	10	18[7]						

Table 79.—Legal Standards for Dairy Products by States (Continued)

	Milk			Skim Milk	Cream	Butter		Sweetened Condensed Milk		Unsweetened Evaporated Milk		Plain Ice Cream		Fruit or Nut Ice Cream		Whole Milk Cheese			Skim Milk Cheese		
	Butter Fat %	Solids Not Fat %	Total Solids %	Total Solids %	Butter Fat %	Butter Fat %	Water %	Butter Fat %	Total Milk Solids %	Butter Fat %	Total Solids %	Butter Fat %	Total Milk Solids %	Butter Fat %	Total Milk Solids %	(a) Butter Fat %	Total Solids %	Water %	Butter Fat %	Total Solids %	Water %
South Dakota........	3.25	8.5	11.75	......	18	80	......	7.7	28	7.7	28	12	......	10	......	50	......	......	....	......	......
Tennessee...........	3.5	8.5	12	......	......	80	......	7.7	28	7.7	28	8	18	6	16	......	......	......	....	......	......
Texas...............	[1]	[1]	[1]	......	18	......	......	8	28	7.8[3]	25.5[3]	8	......	6	......	50	......	39	....	......	......
Utah................	3.2	8.3	11.5	8.5	18[26]	80	......	7.8	25	7.8	25.5	12	28	9	26	50	......	39	Less than 30	......	......
Vermont.............	3.25	8.5	11.75	8.5	18	80	16	8	28	7.8	25.5	14	......	12	......	50	......	39	....	......	......
Virginia............	3.25	8.5	11.75	9.25	18	80	......	7.8	25.5	7.8	25.5	10	35	8	35	50	......	......	....	......	......
Washington..........	3.25	8.5	......	8.8	18	80	......	7.8	25.5	7.8	25.5	10	20	10	20	50	......	......	Less than 12	......	......
West Virginia........	3	8.5	11.5	9	18	80	16	7.8	28	7.8	25.5	8	10	......	......	50	......	......	....	......	......
Wisconsin...........	3	8.5	......	9	18	82.5[42]	......	8[43]	28[43]	8[43]	26.15[43]	13	[44]	11	[44]	50[45]	......	[45]	....	......	......
Wyoming.............	3	8.5	11.5	9.25	18[26]	80	......	8	28	7.8	25.5	10	......	10	......	50	......	39	[1]	......	......

*Compiled from data assembled by the U. S. Dept. of Agr., Bureau of Dairying, B. D. I. M. 583, (1936).

(a) 50% means fat is 50% of the T. S.
1 Defined without numerical standard.
2 Whipping cream 30%.
3 Sum of percentages of fat and solids shall be not less than 33.7%.
4 Where no numerical standard, ruling of U. S. Dept. Agr. is followed.
5 Part-skim No. 1, fat is 27% or more, and is less than 50% of T. S. Part-skim No. 2, fat is 16.5% or more, and is less than 27% of T. S. When less than 16.5% fat, must be labeled "skim."
6 No general law applying to dairy products.
7 Weight of ice cream not less than 1.6 lbs. of T. S. per gal.
8 Maximum moisture: Cheddar 38%, Granular 40%, Monterey 44%, High Moisture Jack 50%.
9 Part-skim, fat 30% and less than 50% of T. S.; Cream cheese, fat 65% of T. S.; Cottage cheese, 4% fat.
10 Light, 16% fat; medium, 26% fat; heavy, 36% fat.
11 By weight; not less than 1.6 lb. of T. S. per gal.
12 Requirements change as Federal requirements change.
13 Idaho adopts standards of purity and strength promulgated by U. S. Dept. Agr.
14 Brick: Fat, 50% of T. S.; water, 42%. Swiss: Fat, 45% of T. S.; water, 39%. Pasteurized or blended must be so labeled. Tolerance allowed in each case, 1%.
15 Must be so labeled ("skim").
16 Less than 11.5% T. S., or less than 3% fat.
17 Must weigh not less than 4½ lbs. per gal. when packed.
18 Percentage of T. S., 33.0.
19 Is cheese made from milk from which any portion of butter fat has been removed.
20 Pasteurization of ice cream mix required. 1% harmless filler permitted.
21 May be sold if plainly labeled "skim milk."
22 Must be made from legal whole milk.
23 Medium: 25% fat; Heavy, 34% fat; Extra heavy, 38% fat
24 Spec. grav. 1.029 to 1.033.
25 Spec. grav. 1.032 to 1.037.
26 Whipping cream, 30% fat.
27 Must contain 1.6 lb. of T. S., and 0.9 lb. T. M. S. per gal.
28 Must be made from 3% fat milk.
29 From milk containing less than 3% fat. Must be labeled.
30 Light, 18% fat; Medium, 25% fat; heavy, 36% fat.
31 Not less than 1.6 lb. T. S. per gal.
32 Must be made from whole milk.
33 "Medium skim," 13% fat; "Special skim," 18% fat. Must be labeled.
34 Light, 18% fat; medium, 30% fat; heavy, 40% fat.
35 Ohio full cream, 30% fat; Ohio standard, 21-29% fat; "skimmed cheese," less than 21% fat.
36 Must be labeled as to its true formula.
37 "Sub-standard" ice cream: Less than 12 to 6% fat.
"Ice Milk": Less than 6 to 3.2% fat.
"Ice Skimmed Milk": Less than 3.2% fat.
38 May be sold, when sweet, wholesome, labeled as skim milk.
39 "Full Cream," 32% fat; "Three-fourth Cream," 24% fat; "One-half Cream," 16% fat; "One-fourth Cream," 8% fat.
40 1.8 lb. T. S. per gal.; 4.75 lbs. per gal.
41 Containing less than 8% fat. Must be branded "Skimmed Cheese."
42 Tolerance, 2.5%.
43 With allowable tolerance.
44 Overrun shall not exceed 100%.
45 Percent fat of T. S.: Cheddar, 50%; Swiss, 45%; Water in Cheddar, 39% max., tolerance 1%; Swiss and Brick, no standard.

to butter,' or if in any way the substance is made to hold 'abnormal quantities of water, milk or cream,' the substance or commodity is to be recognized and treated as 'adulterated butter' under the act.

"(g) Renovated butter having 16 per cent or more of moisture will be held to contain 'abnormal quantities of water, milk or cream,' and be, therefore, classed as 'adulterated butter.'"

The fundamental distinction between butter and renovated butter is that for butter to be subject to the definition and regulations of renovated butter, it must have been melted. It is no longer butter in the sense of the product resulting from the churning of milk or cream. It is a product devoid of the original structure of butter provided by the churning process.

The manufacturer of renovated butter must register annually with the collector of the district of his place of business, pay an annual operator's license fee of $50.00, and is assessed a tax of one-fourth of one cent per pound of renovated butter made.

REFERENCES

1. KIEFFER, P. H., N. Y. Prod. Rev. and Am. Cry. 220, (1923).

CHAPTER XXV

FACTORY TESTS

The factory tests for which directions are given herein, are intended for the guidance of the average commercial creamery. It is beyond the scope of this volume to provide methods for laboratory control, that require expert technical knowledge and equipment for chemical and bacteriological analysis. For such directions the reader is referred to standard treatises on methods of chemical and bacteriological analyses of food products in general, and of dairy products in particular.

ACID TESTS

DETERMINATION OF TITRATABLE ACIDITY IN MILK, CREAM, SKIM MILK, STARTER AND BUTTERMILK

Principle of Acid Tests.—Acid titration tests, as used in the creamery, are based on the principle that a given volume of a normal solution of an alkali, neutralizes the same volume of a normal solution of an acid. By the term "normal solution" is understood a solution so prepared that one liter (1,000 cc.) shall contain the hydrogen equivalent of the active reagent weighed in grams.

The acid is calculated as lactic acid and the alkali used is sodium hydroxide. Both of these agents are monovalent, hence the hydrogen equivalent in each case means the molecular weight. The molecular weight of lactic acid ($C_3H_6O_3$) is 90, and the molecular weight of sodium hydroxide (NaOH) is 40. Therefore, each cc. of a normal solution of sodium hydroxide will neutralize $\frac{90}{1,000} = .09$ grams of lactic acid.

In order to augment the sensitiveness and accuracy of the acid titration test, alkaline solutions weaker than a normal solution are used. Thus, for creamery work, the alkaline solution used is a tenth normal solution of sodium hydroxide ($\frac{N}{10}$NaOH). Therefore, each cc. of the alkaline solution will neutralize $\frac{.09}{10} = .009$ grams of lactic acid.

In order to know when enough alkali solution has been added to reduce all the titratable acid and to render the liquid (milk, or cream, etc.) neutral, a color indicator is used that shows a different color in the presence of an acid than in the presence of an alkali. Of the several indicators available, that known as phenolphthalein is most commonly used for acid tests of dairy products. In acid solutions phenolphthalein is colorless, in alkaline solutions it is pink. In making the acid test, therefore, enough of the alkali solution is added to the measured sample of milk or cream to cause the appearance of a faintly pink color.

MAKING THE ACID TEST

Apparatus Needed.—50 cc. burette, graduated to 0.1 cc., with stand and connections, with supply of sodium hydroxide solution in bottle, and pinch cock.

Titrating cup (white), and stirring rod.

17.6 cc. pipette for milk, skim milk or buttermilk.

18 cc. pipette for cream.

Reagents.—Tenth normal solution of sodium hydroxide in bottle provided with soda-lime tube to protect the alkali solution against CO_2.

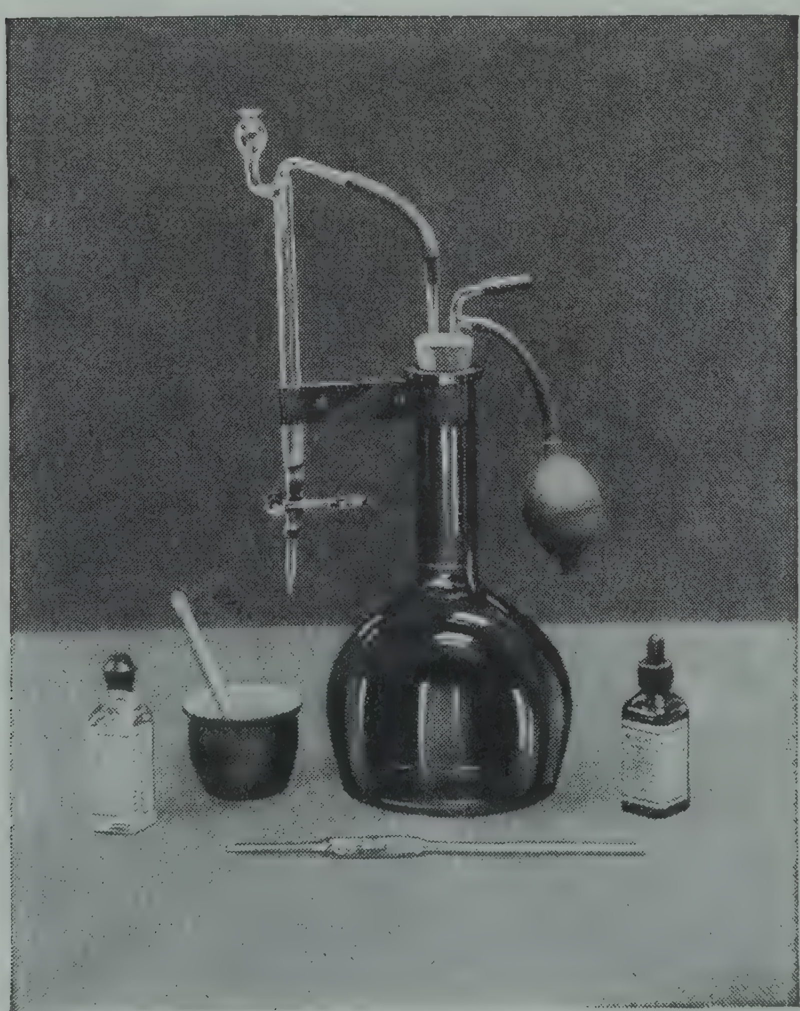


Fig. 122. Nafis acidity tester
Courtesy of Kimble Glass Co.

Phenolphthalein indicator, made up by dissolving one-half gram of dry phenolphthalein powder in 50 cc. of alcohol and, when dissolved, diluting the solution to 100 cc. with distilled water.

Complete acid test outfit, including glassware and reagents may be obtained from dairy supply houses.

Determination.—Measure the milk or cream into the white cup with pipette. Use the 17.6 cc. pipette for milk, skim milk or buttermilk. Use the 18 cc. pipette for cream and rinse pipette with one filling of clean water and pour rinsings into the white cup too. Add 5 to 6 drops of indicator. Fill the burette to the "O" mark with alkali solution, and run the alkali slowly from the burette into the white cup, while constantly stirring the milk product in the cup until it turns a faint pink throughout. The number of cc. of alkali solution used as shown on the burette, divided by 20 gives the per cent acid.

$$\frac{\text{cc. Alk. Sol.} \times .009}{18} \times 100 = \frac{\text{cc. Alk. Sol.}}{20} = \%\ \text{acid}$$

Example:

7.4 cc. of $\frac{N}{10}$ alkali solution are required to turn 18 cc. of cream pink. The cream, therefore, contains $\frac{7.4}{20} = 0.37\%$ acid. Some operators prefer the use of a 9 cc. pipette to an 18 cc. for the cream sample. In such case the cc. alkali solution required for the test are divided by 10.

$$\frac{\text{cc. Alk. Sol.} \times .009}{9} \times 100 = \frac{\text{cc. Alk. Sol.}}{10} = \%\ \text{acid}$$

Example:

3.7 cc. of $\frac{N}{10}$ alkali solution are required to turn the 9 cc. of cream pink. The cream, therefore, contains $\frac{3.7}{10} = 0.37\%$ acid.

In the case of raw cream that is gassy, such as is the case with most of the cream testing 0.65% or more of acid, the carbon dioxide present causes the test to be erroneously high (usually about 0.05% too high). Boiling the sample of such cream will drive off most of the CO_2, and will yield a more nearly accurate test.

The same applies to cream that is neutralized with soda (Na_2CO_3) or baking soda ($NaHCO_3$), unless pasteurized by the

flash process (180° F. or higher). It was shown in Chapter X on "Neutralization," that when sour cream is neutralized with soda neutralizer and pasteurized by low-temperature vat pasteurization (145° for 30 minutes), the expulsion of the CO_2 produced in the cream by the neutralizer is incomplete, causing the CO_2 content of the cream at churning time to give an erroneously high acid test. In flash pasteurization this gas is usually largely expelled and the acid test corresponds reasonably closely with the acidity aimed at in the calculations of the amount of neutralizer used. Vat-pasteurized, soda-neutralized cream should, therefore, be boiled for the acid test. When using lime neutralizer, boiling of the sample of vat-pasteurized cream is not necessary.

If the cream in the vat is foamy, having air whipped into it, the 18 cc. or 9 cc. pipette will contain less than the required weight of cream (18 or 9 grams, respectively), and the acid test will be erroneously low. Such cream should be weighed for the test and not measured, using 18 grams or 9 grams, respectively.

In European countries they prefer to express the acid test in terms of cc. standard sodium hydroxide solution required, which they call degrees. The most prevalent acid test they use is the Soxhlet Henkel test (S.H.) In this test a 100 cc. cream sample and one-fourth normal $\left(\frac{N}{4}\right)$ solution of sodium hydroxide are used. The results are expressed in terms of degrees S.H., 1 degree S.H. acid represents 1 cc. $\frac{N}{4}$ sodium hydroxide solution, hence $1^\circ \text{ S.H.} = \frac{90}{4 \times 1000} = 0.0225\%$ lactic acid.

Examples of Conversion.—

$28^\circ \text{ S.H.} = 28 \times .0225 = 0.63\%$ acid.

$0.25\% \text{ lactic acid} = \frac{.25}{.0225} = 11.1^\circ \text{ S.H.}$

RAPID ACID TEST

In some cases it is desirable to determine rapidly whether the milk or cream in some of the individual cans on the receiving floor is above or below certain standards of acidity. The cream grading regulations in many of the states now specify a max-

imum acid limit for different grades of cream, such as 0.2% for sweet cream, and 0.4 or 0.6% for No. 1 sour cream. In such case the problem is not so much one of determining the exact per cent acid, as it is to find out whether certain cans fall within the acid limit of the respective grade.

Equipment.—In order for acid testing of individual cans to be practicable, the method must be sufficiently simple and rapid to not delay the routine operation of cream grading. For this purpose it has been found suitable to use an ordinary wide-mouth quart jar for the standard alkali solution, to have it also contain the phenolphthalein indicator, to have the solution of such strength that a given amount of the alkali solution neutralizes 0.2% acid in an equal amount of cream, to use dippers of the same size for the sample of cream and for the addition of alkaline solution, and to provide a box mounted on a frame on casters for the testing equipment, consisting of quart jar containing the alkaline solution with indicator, the white cup for titration, and one dipper each for the cream sample and for the alkaline solution. The testing equipment can thus be readily moved over the grading floor.

Reagents.—Since most creameries are using tenth normal sodium hydroxide for their regular acid tests of cream in connection with neutralization and for the control of the churning acidity, it has been found most practical to adopt the $\frac{N}{10}$ sodium hydroxide solution as the basis for the test solution used in the rapid acid test.

One quart of alkaline solution holds 946.36 cc. To secure the correct strength of alkaline solution, add 210.5 cc. of the $\frac{N}{10}$ sodium hydroxide to the quart jar, 15 cc. of phenolphthalein indicator, and fill the jar with distilled water.

Proof.—

$\frac{4}{1{,}000} \times 210.5 = 0.842$ grams of sodium hydroxide.

$4 : 9 = 0.842 : X$; $X = 1.8945$ grams of acid neutralized.

$\frac{1.8945}{946.36} = .002$ grams acid, or 0.2% acid which a given amount of the alkali solution will neutralize in an equal amount of cream.

Making the Rapid Acid Test.—

Use 20 cc. dippers.

1. Pour one dipperful of cream from the can into the white cup. Add one dipperful of alkaline solution to the white cup and stir. If the pink color remains, the cream contains less than 0.2% acid.

2. If the pink color disappears, the cream contains more than 0.2% acid. Now add a second dipperful of alkaline solution and stir. If the cream color remains, the cream contains less than 0.4% acid.

3. If the pink color of (2) again disappears, the cream contains more than 0.4% acid. Now add a third dipperful of alkaline solution and stir. If the pink color remains, the cream contains less than 0.6% acid. If the pink color disappears, the cream contains more than 0.6% acid.

4. In general practice it is not necessary to test each can of cream for acid. However, the grader should test several cans each day when starting to grade, so as to confirm the accuracy of his sense of taste and his judgment. The test should be made also on all border-line cans, regarding the acid of which the grader is in doubt.

CHECKING THE STRENGTH OF THE ALKALI SOLUTION USED FOR ACID TESTS

For accurate acid tests of milk and cream it is indispensable that the alkali solution be of the correct strength. It is advisable, therefore, to check the strength of the alkali solution. This should be done with the new solution just purchased or made up, and again at intervals of about once per week. The checking is readily done by titrating the $\frac{N}{10}$ alkali solution against a standard acid solution of known strength as follows:

Apparatus and Reagent.—

10 cc. pipette

$\frac{N}{4}$ — hydrochloric acid

Determination.—With the 10 cc. pipette transfer 10 cc. of the fourth normal solution of hydrochloric acid to the titrating cup. Add a few drops of phenolphthalein indicator and titrate with the standard alkali solution from the 50 cc. burette. Stop

the titration when a faint pink color persists for about 15 seconds. The end point is quite distinct. If the alkali solution is of the correct strength, it will require 40 cc. to neutralize the 10 cc. of acid. The reading on the burette should be not lower than 39 cc. nor higher than 41 cc. If the amount of alkali solution required falls outside of this range, shake the bottle and titrate again. If the titration is still outside of the above range, discard the alkali solution and make up or purchase a new one.

SPECIFIC GRAVITY OF MILK AND SKIM MILK

Lactometer Method.—The primary purpose of testing milk and skim milk purchased by the creamery for specific gravity, is to determine the presence or absence of extraneous water in milk or skim milk that is used for starter making. Diluted milk, or milk with an abnormally low solids content, is unsuitable for starter work.

The lactometer method provides a rapid and reasonably accurate means to determine the specific gravity of these milk products. The Quevenne lactometer with thermometer and with a scale graduated from 15 to 40, is the lactometer most commonly used. In addition, a hydrometer cylinder, about 10 inches high and one and one-half inches in diameter, is needed.

The Quevenne lactometer is graduated to record the correct specific gravity at 60° F. The milk should, therefore, be tested at this temperature. At a temperature higher or lower than 60° F., the reading may be corrected by adding (when above 60° F.) or deducting (when below 60° F.) one-tenth point to or from the reading for each degree Fahrenheit above or below 60° F. This arbitrary correction lacks in accuracy, however, beyond a temperature range of 55 to 65° F. It is preferable to take the reading at or very near 60° F.

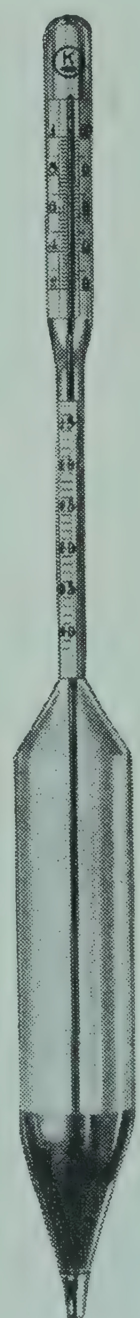


Fig. 123. Quevenne lactometer
Courtesy of Kimble Glass Co.

Determination.—Temper the milk to 60° F.

and fill the hydrometer cylinder. Insert the lactometer and when it is in equilibrium take the reading. It will be noted that the milk climbs up slightly on the stem of the lactometer. The meniscus so formed should not be included in the reading. The correct reading is obtained by sighting along the surface of the milk and noting the point on the scale that corresponds with the milk level.

The specific gravity is calculated by simply adding 1,000 to the lactometer reading and dividing the sum by 1,000.

Example:

Lactometer reading is 31 at 65° F.

Corrected reading is $31 + 0.5 = 31.5$

Specific gravity is $\frac{31.5+1{,}000}{1{,}000} = 1.0315$

The specific gravity of normal milk averages approximately 1.032. When it drops below 1.029, there is reasonable cause for suspecting it to contain added water. The average specific gravity of skim milk is approximately 1.036. When it drops below 1.034, it usually contains added water.

Table 80. Specific Gravity and Weight per Gallon of Milk and Cream*

Percentage of Fat (By Weight)	Specific Gravity 20°/4° C.	Specific Gravity 10°/4° C.	Pounds Per Gallon at 20° C. (68° F.)	Pounds Per Gallon at 10° C. (50° F.)
0.025	1.035	1.037	8.63	8.65
1	1.034	1.036	8.62	8.64
2	1.033	1.035	8.61	8.63
3	1.032	1.034	8.60	8.62
4	1.031	1.033	8.59	8.61
5	1.029	1.032	8.58	8.60
6	1.028	1.031	8.57	8.59
7	1.027	1.030	8.56	8.59
8	1.026	1.029	8.55	8.58
9	1.024	1.028	8.54	8.57
10	1.023	1.027	8.53	8.56
15	1.016	1.022	8.47	8.52
20	1.011	1.017	8.43	8.48
25	1.007	1.014	8.39	8.45
30	1.002	1.011	8.36	8.43
35	.998	1.008	8.31	8.40
40	.993	1.005	8.28	8.38

*U. S. Bur. Standards, Letter Circular L. C. 96, 1923. Figures based on values of spec. gr. and coefficient of expansion determined by Bureau of Standards.

For accurate results with the lactometer, the milk or skim milk must be in normal physical condition, free from foam and from visible precipitation of curd. The lactometer does not yield dependable readings in the case of cream, starter and buttermilk. The specific gravities and the weights per gallon for milk and cream of various percentages of fat are given in Table 80.

TOTAL SOLIDS

By Means of the Babcock Formula.—For rapid and reasonably accurate work the total solids of milk may be determined by the use of the Babcock formula, which is as follows:

$$\text{Total solids} = \frac{L}{4} + 1.2 \times f.$$

L = Quevenne lactometer reading.

f = per cent of fat.

Example: Lactometer reading is 32; per cent fat is 4.

$$\text{Total solids} = \frac{32}{4} + \left(1.2 \times 4\right) = 12.8\%$$

For the determination of the solids not fat use the formula:

$\frac{L}{4} + \left(.2 \times f.\right) =$ per cent solids not fat; or deduct the per cent fat from the per cent total solids.

Table 81 shows the per cent total solids in skim milk, and in milk of various fat contents, when the per cent fat and the Quevenne lactometer readings are known. The Babcock formula for the determination of the per cent total solids and solids not fat is applicable only to milk and skim milk. For cream and buttermilk the gravimetric method is recommended.

Gravimetric Method.—"Heat from three to five grams of milk, skim milk or buttermilk at the temperature of boiling water until it ceases to lose weight, using a tared flat dish of not less than 5 cm. diameter. If desired, from fifteen to twenty grams of pure, dry sand may be previously placed in the dish. Cool in a desiccator and weigh rapidly to avoid absorption of hygroscopic moisture. In the case of cream use only two to three grams of sample."

Table 81.—Per Cent Total Solids, When Per Cent Fat and Quevenne Lactometer Reading at 60° F. are Known

Fat per cent	Quevenne lactometer reading at 60° F.										
	26	27	28	29	30	31	32	33	34	35	36
	Total solids %	Total solids %	Total solids %	Total solids %	Total solids %	Total solids %	Total solids %	Total solids %	Total solids %	Total solids %	Total solids %
0.0	6.50	6.75	7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00
0.1	6.62	6.87	7.12	7.37	7.62	7.87	8.12	8.37	8.62	8.87	9.12
0.2	6.74	6.99	7.24	7.49	7.74	7.99	8.24	8.49	8.74	8.99	9.24
0.3	6.86	7.11	7.36	7.61	7.86	8.11	8.36	8.66	8.86	9.11	9.36
0.4	6.98	7.23	7.48	7.73	7.98	8.23	8.48	8.73	8.98	9.23	9.48
0.5	7.10	7.35	7.60	7.85	8.10	8.35	8.60	8.85	9.10	9.35	9.60
0.6	7.22	7.47	7.72	7.97	8.22	8.47	8.72	8.97	9.22	9.47	9.72
0.7	7.34	7.59	7.84	8.09	8.34	8.59	8.84	9.09	9.34	9.59	9.84
0.8	7.46	7.71	7.96	8.21	8.46	8.71	8.96	9.21	9.46	9.71	9.96
0.9	7.58	7.83	8.08	8.33	8.58	8.83	9.08	9.33	9.58	9.83	10.08
1.0	7.70	7.95	8.20	8.45	8.70	8.95	9.20	9.45	9.70	9.95	10.20
1.1	7.82	8.07	8.32	8.57	8.82	9.07	9.32	9.57	9.82	10.07	10.32
1.2	7.94	8.19	8.44	8.69	8.94	9.19	9.44	9.69	9.94	10.19	10.44
1.3	8.06	8.31	8.56	8.81	9.06	9.31	9.56	9.81	10.06	10.31	10.56
1.4	8.18	8.43	8.68	8.93	9.18	9.43	9.68	9.93	10.18	10.43	10.68
1.5	8.30	8.55	8.80	9.05	9.30	9.55	9.80	10.05	10.30	10.55	10.80
1.6	8.42	8.67	8.92	9.17	9.42	9.67	9.92	10.17	10.42	10.67	10.92
1.7	8.54	8.79	9.04	9.29	9.54	9.79	10.04	10.29	10.54	10.79	11.04
1.8	8.66	8.91	9.16	9.41	9.66	9.91	10.16	10.41	10.66	10.91	11.17
1.9	8.78	9.03	9.28	9.53	9.78	10.03	10.28	10.53	10.78	11.03	11.29
2.0	8.90	9.15	9.40	9.65	9.90	10.15	10.40	10.66	10.91	11.16	11.41
2.1	9.02	9.27	9.52	9.77	10.02	10.27	10.52	10.78	11.03	11.28	11.53
2.2	9.14	9.39	9.64	9.89	10.14	10.39	10.64	10.90	11.15	11.40	11.65
2.3	9.26	9.51	9.76	10.01	10.26	10.51	10.76	11.02	11.27	11.52	11.77
2.4	9.38	9.63	9.88	10.13	10.38	10.63	10.88	11.14	11.39	11.64	11.89
2.5	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.26	11.51	11.76	12.01
2.6	9.62	9.87	10.12	10.37	10.62	10.87	11.12	11.38	11.63	11.88	12.13
2.7	9.74	9.99	10.24	10.49	10.74	10.99	11.24	11.50	11.75	12.00	12.25
2.8	9.86	10.11	10.36	10.61	10.86	11.11	11.37	11.62	11.87	12.12	12.37
2.9	9.98	10.23	10.48	10.73	10.98	11.23	11.49	11.74	11.99	12.24	12.49
3.0	10.10	10.35	10.60	10.85	11.10	11.36	11.61	11.86	12.11	12.36	12.61
3.1	10.22	10.47	10.72	10.97	11.23	11.48	11.73	11.98	12.23	12.48	12.74
3.2	10.34	10.59	10.84	11.09	11.35	11.60	11.85	12.10	12.35	12.61	12.86
3.3	10.46	10.71	10.96	11.22	11.47	11.72	11.97	12.22	12.48	12.73	12.98
3.4	10.58	10.83	11.09	11.34	11.59	11.84	12.09	12.34	12.60	12.85	13.10
3.5	10.70	10.95	11.21	11.46	11.71	11.96	12.21	12.46	12.72	12.97	13.22
3.6	10.82	11.08	11.33	11.58	11.83	12.08	12.33	12.58	12.84	13.09	13.34
3.7	10.94	11.20	11.45	11.70	11.95	12.20	12.45	12.70	12.96	13.21	13.46
3.8	11.06	11.32	11.57	11.82	12.07	12.32	12.57	12.82	13.08	13.33	13.58
3.9	11.18	11.44	11.69	11.94	12.19	12.44	12.69	12.94	13.20	13.45	13.70
4.0	11.30	11.56	11.81	12.06	12.31	12.56	12.81	13.06	13.32	13.57	13.83
4.1	11.42	11.68	11.93	12.18	12.43	12.68	12.93	13.18	13.44	13.69	13.95
4.2	11.54	11.80	12.05	12.30	12.55	12.80	13.05	13.31	13.56	13.82	14.07
4.3	11.66	11.92	12.17	12.42	12.67	12.92	13.18	13.43	13.68	13.94	14.19
4.4	11.78	12.04	12.29	12.54	12.79	13.04	13.30	13.55	13.80	14.06	14.31
4.5	11.90	12.16	12.41	12.66	12.91	13.16	13.42	13.67	13.92	14.18	14.43
4.6	12.03	12.28	12.53	12.78	13.03	13.28	13.54	13.79	14.04	14.30	14.55
4.7	12.15	12.40	12.65	12.90	13.15	13.40	13.66	13.91	14.16	14.42	14.67
4.8	12.27	12.52	12.77	13.02	13.27	13.52	13.78	14.03	14.28	14.54	14.79
4.9	12.39	12.64	12.89	13.14	13.39	13.64	13.90	14.15	14.40	14.66	14.91
5.0	12.51	12.76	13.01	13.26	13.51	13.76	14.02	14.27	14.52	14.78	15.03
5.1	12.63	12.88	13.13	13.38	13.63	13.89	14.14	14.39	14.64	14.90	15.15
5.2	12.75	13.00	13.25	13.50	13.75	14.01	14.26	14.51	14.76	15.02	15.27
5.3	12.87	13.12	13.37	13.62	13.87	14.13	14.38	14.63	14.88	15.14	15.39
5.4	12.99	13.24	13.49	13.74	14.00	14.25	14.50	14.76	15.01	15.26	15.51
5.5	13.11	13.36	13.61	13.86	14.12	14.37	14.62	14.88	15.13	15.38	15.63
5.6	13.23	13.48	13.73	13.99	14.24	14.49	14.75	15.00	15.25	15.50	15.75
5.7	13.35	13.60	13.85	14.11	14.36	14.61	14.87	15.12	15.37	15.62	15.87
5.8	13.47	13.72	13.97	14.23	14.48	14.74	14.99	15.24	15.49	15.74	15.99
5.9	13.59	13.84	14.10	14.35	14.60	14.86	15.11	15.36	15.61	15.86	16.12

TESTING MILK, CREAM, SKIM MILK AND BUTTERMILK FOR BUTTER FAT

THE BABCOCK TEST

Principle of Babcock Test.—The principle of the Babcock test is based on the fact that when sulphuric acid in sufficient strength and amount is added to milk, cream or other dairy product, the acid breaks down the non-fatty constituents without materially affecting the fat. The action of the acid, together with the heat generated, destroys the emulsion of fat-in-milk serum, causing the fat to separate out. The completeness of this separation is facilitated by subjecting the mixture of acid and milk to centrifugal force.

In order to make possible the ready measurement of this practically pure, separated fat in terms of per cent, the neck of the test bottle, in which the fat appears in the finished test, is graduated. Each one per cent graduation has a capacity of .2 cc. The specific gravity of butter fat at about 135° F., which is the temperature at which the test is read, averages .9 grams. The .2 cc. of butter fat therefore weighs $.2 \times .9 = .18$ grams. In order to have .18 grams butter fat represent 1% of the milk or cream tested, $.18 \times 100$ or 18 grams of milk or cream must be used.

In the case of milk the sample is measured, instead of weighed into the test bottle. The average specific gravity of milk is 1.032. Hence 18 grams of milk have a volume of $\frac{18}{1.032}$ or 17.44 cc. But when milk is poured from the pipette, approximately .15 cc. remains in the pipette and fails to be discharged into the test bottle. For this reason a 17.6 cc. pipette is used which delivers 18 grams of milk.

In the case of cream, the specific gravity varies greatly with the richness of the cream and the amount of foam it contains, hence the measuring of the cream into the test bottle introduces considerable error. For this reason the cream is weighed into the test bottle, using 9 grams or 18 grams. Where a 9 gram test bottle is used, each 1% of the graduation has a capacity of .1 cc. which corresponds to .09 gram of butter fat. In the use of these so-called 9 gram cream test bottles, therefore, $.09 \times 100$, or 9 grams of cream are weighed into the test bottle and the graduation again represents per cent.

STANDARD BABCOCK GLASSWARE*

Milk Test Bottle.—8% 18 gram test bottle graduated to 0.1%.

Cream Test Bottles.—50% 9 gram short neck (6 inch) cream test bottle graduated to 0.5%, or

50% 9 gram long neck (9 inch) cream test bottle graduated to 0.5%, or

50% 18 gram long neck (9 inch) cream test bottle, graduated to 0.5%.

Pipettes.—17.6 cc. capacity for milk, 9 cc. or 18 cc. for use in weighing cream.

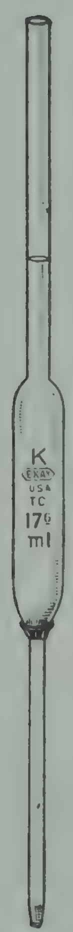


Fig. 124. 17.6 cc. milk pipette

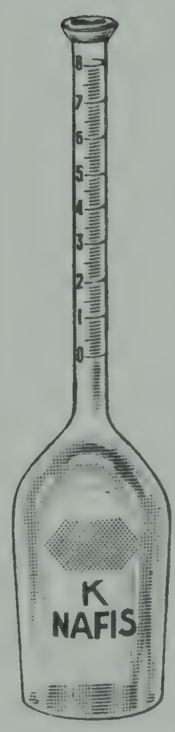


Fig. 125. 8% milk test bottle

Fig. 126. 50% 9 gram cream test bottle

Fig. 127. 50% 18 gram long neck cream test bottle

Fig. 128. 50% 9 gram long neck cream test bottle

U. S. Standard glassware for Babcock test. Courtesy of Kimble Glass Co.

Acid cylinder or dipper 17.5 cc.

Cream Testing Scales.—Sensibility reciprocal of 30 mgms., i.e., the addition of 30 mgms. to the balanced scales when loaded

*The specifications for this glassware were originally designed by the joint action of the American Dairy Science Association, the U. S. Dairy Division and the U. S. Bureau of Standards in 1911. The glassware has been approved and adopted as "Standard Babcock Glassware" by the American Dairy Science Association, the U. S. Bureau of Standards, and the Association of Official Agricultural Chemists.

to capacity shall cause a deflection of the pointer of at least one division on the graduation.

Weights.—9 gram or 18 gram accurate to 10 mgms.

Centrifuge or Tester.—The proper speed of the centrifuge is shown below:

Diameter of wheel, inches	10	12	14	16	18	20	22	24
Revolutions per minute	1074	980	909	848	800	759	724	693

By diameter of wheel is meant the distance between the inside bottoms of opposite cups through the center of rotation of the centrifuge wheel while the cups are horizontally extended.

Speed Indicator; water bath with thermometer, and with overflow approximately level with top graduation on neck of test bottles; dividers or calipers; and test bottle brushes.

REAGENTS

Commercial sulphuric acid, specific gravity 1.82 to 1.83.

Glymol or white mineral oil of high grade, preferably colored red with "Oil Red" at the rate of 1 gram oil red to 1 gallon of oil. Glymol is used for cream tests only.

OPERATION OF BABCOCK TEST

Milk Test.—The sampling of milk is fully discussed in Chapter IX on "Receiving Milk and Cream." Samples containing lumps of cream or butter granules, and churned samples, should be re-emulsified before testing. This is best done by heating to about 100° F. and shaking vigorously. Curdy samples may be reduced to a homogeneous consistency by the addition of a knife point full of soda, followed by vigorous shaking, or by the use of an egg beater.

Bring the temperature of both, milk and acid, to within the range of 55° to 70° F. This is important. High temperature of milk, or of acid, or both, causes charring that interferes with the accuracy of reading the tests. Transfer 18 grams of the sample to the milk test bottle by means of the 17.6 cc. pipette. The milk remaining in the pipette tip after free outflow has ceased must be blown out. Add 17.5 cc. of sulfuric acid, preferably not all at one time, pouring it down the side of the neck of the bottle in such a way as to wash any traces of the milk into the bulb. Shake until all traces of curd have disappeared; then transfer the bottle to the centrifuge; counter-balance it;

and, after the proper speed has been attained, whirl 5 minutes. Add soft water at 140° F., or above, until the bulb of the bottle is filled. Whirl 2 minutes. Add hot water until the liquid column approaches the top graduation of the scale. Whirl 1 minute longer. Transfer the bottle to the water bath filled with water to the overflow and maintained at a temperature within the range of 130 to 140° F. Hold in water bath for not less than three minutes. Read the test by measuring with calipers from bottom of fat column to top of upper meniscus.

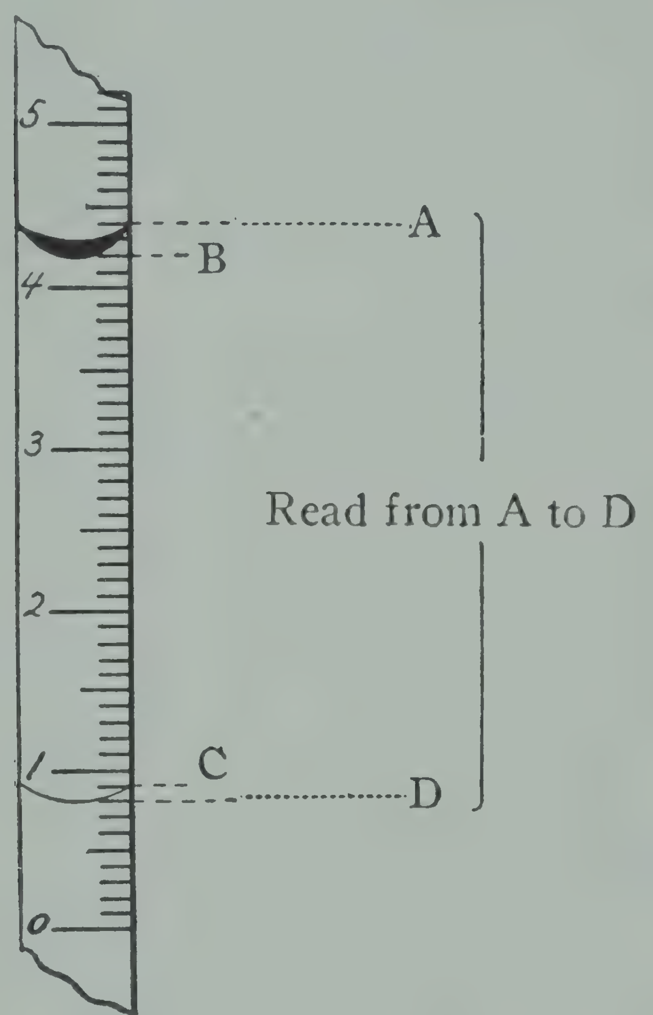


Fig. 129. Reading the milk test

The fat column at the time of reading the test should be clear, translucent, amber color, free from visible curdy or charred particles in the mass of fat and at the bottom of the fat column. Dark color and charred particles are usually due to too strong or too much acid. A turbid, light color is usually due to too weak or too little acid. A layer of curdy material at the bottom of the fat column generally appears when the milk or the acid, or both, are too warm at the time the acid is added. Their temperature should not exceed 70° F. Lower temperatures are preferable.

Cream Test.—The cream sample should be of a free-flowing consistency, free from lumps, and homogeneous. If excessively

thick, or lumpy, temper the samples in a water bath at 85 to 110° F. Mix thoroughly immediately before use for the test. The cream must be weighed into the test bottle, using a 9-gram charge for 9-gram bottles, and an 18-gram charge for 18-gram bottles. It is most conveniently transferred to the properly balanced test bottle on the cream test scales by means of a 9 or 18 cc. pipette. The scales must have the prescribed sensibility reciprocal (30 mgms.), must set level and be protected from air currents. For the manipulation of the test, either Method 1 or Method 2 may be followed.

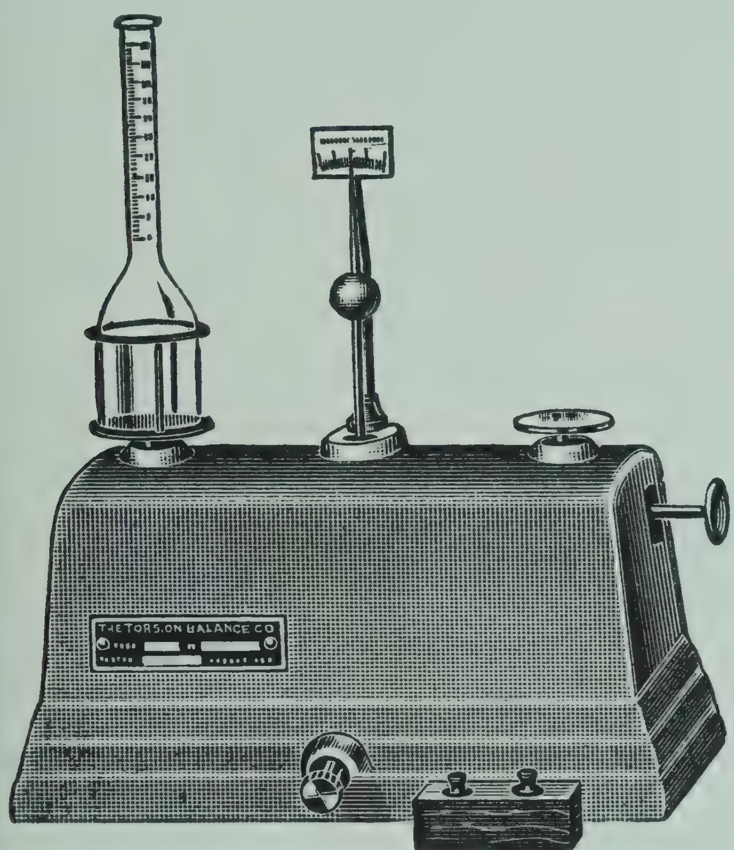


Fig. 130. Cream testing balance
Courtesy of Torsion Balance Co.

Method 1.—After the cream has been weighed into the test bottle, add 8-12 cc. of the sulfuric acid, in the case of the 9-gram bottle, or 14-17 cc. of the acid, in the case of the 18-gram bottle, or add acid until the mixture of cream and acid, after shaking, has assumed a chocolate-brown color. Shake until all lumps have completely disappeared; then add 5-10 cc. of soft water at 140° F., or above. Transfer the bottle to the centrifuge; counter-balance it; and, after the proper speed has been attained, whirl 5 minutes. Add hot water until the liquid column approaches the top graduation of the scale; then whirl 2 minutes longer.

Hold test bottle in water bath at 130 to 140° F. for at least 3 minutes. Add a few drops of glymol (white mineral oil). Read the test by measuring with calipers from bottom of fat column

to bottom of glymol. The purpose of using glymol is to remove the meniscus. The glymol should be allowed to flow down the side of the neck to avoid disturbing and mixing with the fat column. An ordinary oil cup has been found convenient for adding the glymol.

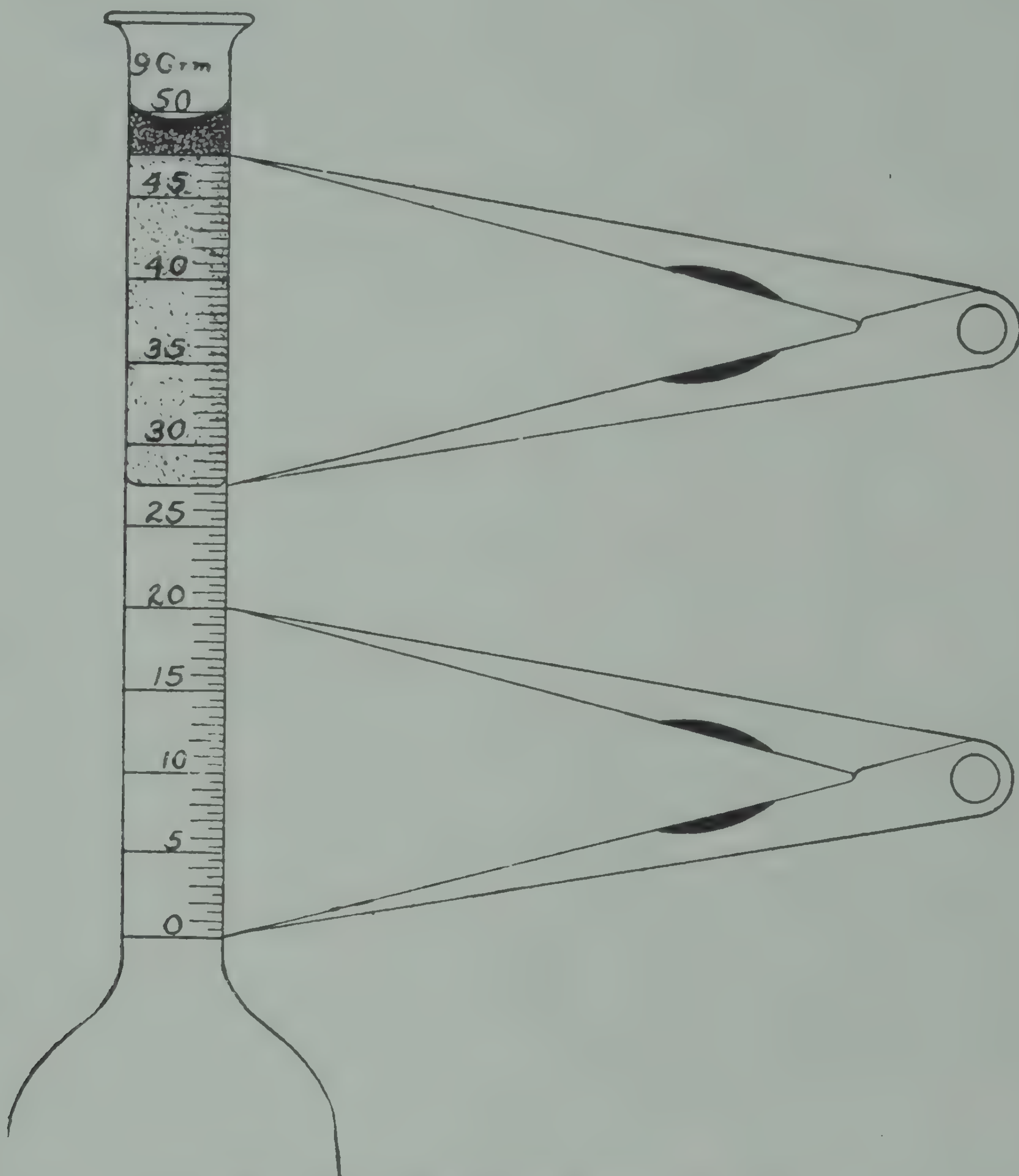


Fig. 131. Reading the cream test

Method 2.—(For a 9-gram bottle only).—After the cream has been weighed into the test bottle, add 9 cc. of soft water at 140° F. or above, and thoroughly mix; add 17.5 cc. of the sulfuric acid and shake until all lumps have completely disappeared. Transfer the bottle to the centrifuge; counterbalance it; and, after the proper speed has been attained, whirl 5 minutes. Fill the bottle to the neck with hot water and whirl 2 minutes. Add hot water until the liquid column approaches the top graduation of the scale; then whirl 1 minute longer. Complete test as indicated under Method 1.

Either of the above two methods will yield a clear, readily readable fat column.

Buttermilk Test.—For the fat test of buttermilk, the modified Babcock test, known as the butyl alcohol test (American Association test), is most suitable for use in the creamery.

Apparatus and Reagents—

Double neck skim milk bottle, with 0.5% graduation.
2 cc. pipette for butyl alcohol.
9 cc. pipette for buttermilk.
17.5 cc. cylinder or dipper for sulphuric acid.
Centrifuge, water bath and calipers, same as for milk.
Sulphuric acid, specific gravity 1.82 to 1.83.
Normal butyl alcohol.

Determination—

To each test bottle add the following in the order stated:

1. 2 cc. normal butyl alcohol.
2. 9 grams of buttermilk sample.
3. 7 to 9 cc. sulphuric acid (one-half acid measure full).

Mix thoroughly by giving bottle a gentle rotary motion, taking care not to allow contents to rise up into graduated neck. Centrifuge 6, 2 and 2 minutes, respectively, adding water (140° F.) and completing the test as directed under "Milk Test." In case the fat is in the lower part of the graduated neck at the time of reading, it may be raised by pressure of the finger on the mouth of the filling tube. Multiply reading by 2 to obtain per cent of fat.

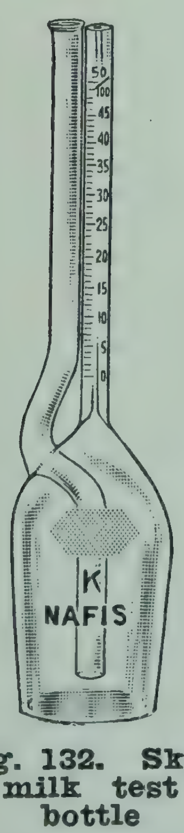


Fig. 132. Skim milk test bottle
Courtesy of Kimble Glass Co.

Skim Milk Test.—Use double neck skim milk bottle with 0.25% graduation, 17.6 cc. pipette, and 20 cc. sulphuric acid. Mix thoroughly by giving the bottle a gentle rotary motion, taking care that contents do not rise into graduated neck. Centrifuge 10, 2 and 2 minutes, respectively, adding water and completing the test as directed under "Milk Test."

Whey Test.—Test whey like skim milk, but use double neck skim milk bottle with 0.5% graduation and only 13 to 17 cc. of sulphuric acid.

TESTING BUTTER FOR MOISTURE, FAT, SALT AND CURD BY THE MODIFIED KOHMAN TEST

For general routine work in the average creamery the daily testing of butter from the churn is usually limited to the determination of moisture and of salt. The sum of the moisture and salt, plus an assumed curd content of not to exceed 1%, deducted from 100, then gives a general idea of the percentage of fat. The procedure is simple, rapid, and has proved to be a practical and fairly dependable factory check on the composition of butter.

Taking Samples of Butter.—It is possible to secure fairly representative portions of butter for analysis by taking several small "dabs' of butter from different points of the mass of the butter to be tested, direct into the evaporating cup, and to proceed with the test without preparing the sample. Tests from unprepared samples usually show surprisingly close agreement with tests from prepared samples. However, the danger is ever-present that such small samples may not be representative of the composition of the butter from which they are taken. Since the representativeness of the sample is the very foundation of the accuracy of the test, it is preferable to take a larger sample, emulsify it thoroughly and then transfer the small amount of butter needed for the test from this prepared sample. Containers for prepared samples are preferably 4 oz. glass jars, with straight sides, and tight-fitting, non-absorbent seal, such as aluminum screw caps with Vinilite liner, or glass or rubber stoppers. The aluminum cap provides a suitable surface for writing the sample identification number on the cap. The sample jar must be clean and thoroughly dry when used.

From Churn.—Bring butter up on worker rolls or shelf. Wipe loose moisture off door frame and take care that no moisture drops into sampling cup from the walls of the churn. Cut top layer off the butter with ladle at points where samples are taken, so as to provide a smooth, solid surface, free from moisture pockets. With spatula or spoon immediately transfer a small portion of butter (about 20 to 30 grams) from the exposed area to the sample jar. Take about 5 to 6 such portions from different parts of the churn. Seal the jar tightly.

From Cubes and Tubs.—Bore the butter diagonally from top to bottom with the trier. Transfer plug to sample jar. Bore

at least two packages from each churning and make test of each sample separately.

From Prints and Rolls.—Quarter the package lengthwise, then cut all quarters transversely in half. Take two diagonally opposite eighths for the sample. The most accurate sample of print butter, however, is obtained by emulsifying the entire print. This will require a larger sample jar. But in case of any doubt as to the composition of any churning in print form, it is wisdom to check the routine method of sampling by using one entire print. In such case, sample at least two prints of each churning in this manner.

Preparation of Sample for Test.—Make sure that the sample jars are tightly sealed. Temper the sample to a soft consistency by setting in water bath at 90 to 95° F. Then shake thoroughly to get a uniform, thick consistency similar to Mayonnaise. Open and stir well with spatula, making sure that all butter is removed from edges of container, that the lumps have all disappeared, and that the color is uniform throughout. The sample is now ready for the test. If not tested immediately, seal it tightly and place in cooler.

DETERMINATION OF MOISTURE

Apparatus.—

Butter trier.
Spatula with stiff, four-inch blade of stainless steel.
Sample jars, four ounce, straight sides, with tight seal.
Aluminum evaporating cups, polished, 2½" x 2½".
Crucible tongs (large size).
Moisture test scales, sensibility reciprocal well within the specifications of the U. S. Bureau of Standards, which are as follows: "The maximum sensibility reciprocal allowable for moisture test scales shall not exceed 1 grain (65 mg.) when the maximum load is placed upon the scale; provided that the manufacturer's sensibility reciprocal on all new scales shall not be greater than one-half of this value." Special Torsion balance No. 1735, or ordinary Torsion balance No. 1705, have been found highly satisfactory. They are, in fact, adjusted to approximately 15 mg. sensibility reciprocal.

Weights. One 10-gram weight for use with special Torsion balance No. 1735, or one 10-gram, and one 9-gram weight for use with ordinary Torsion balance No. 1705.

Electric hot plate with three-heat switch, or gas or alcohol burner with tripod and asbestos mat.

Arrangement for cooling aluminum cups.

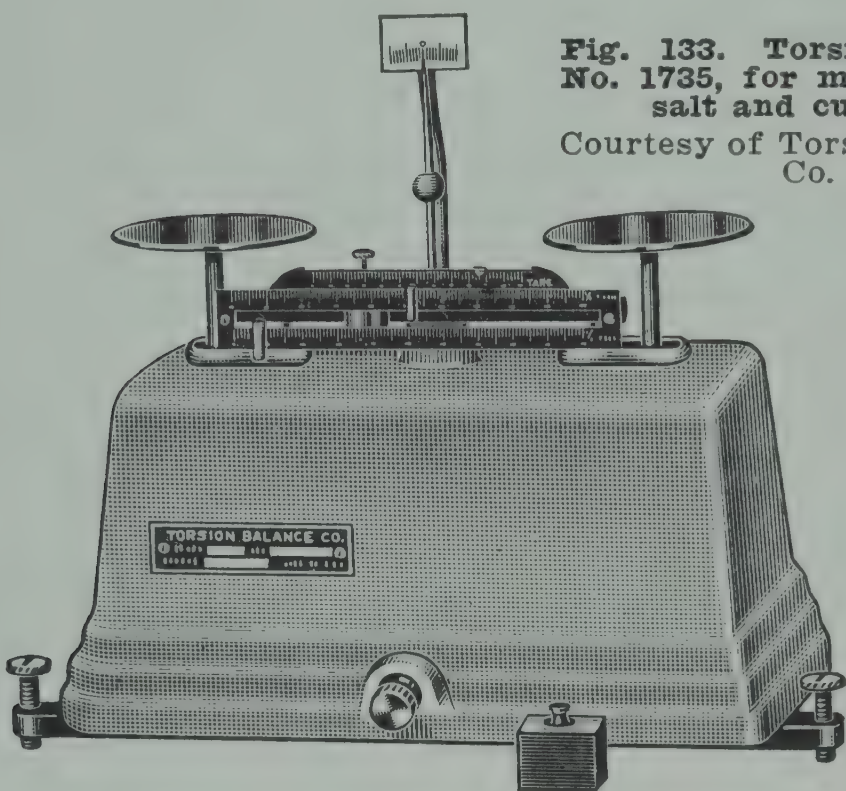


Fig. 133. Torsion Balance No. 1735, for moisture, fat, salt and curd test
Courtesy of Torsion Balance Co.

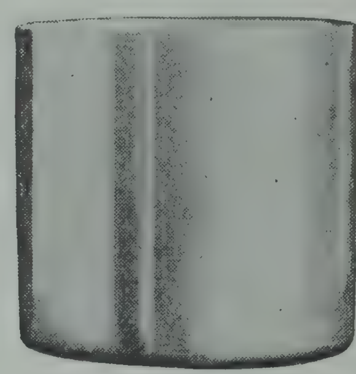


Fig. 134. Moisture test cup

Determination.—Have moisture scales set level, swinging freely, and protected from drafts. When using the special balance (No. 1735), bring into correct balance with the riders at the extreme left of each beam, and tare weight at the extreme right. Place a clean, dry aluminum cup (kept in a dry place at room temperature) on the right hand scale pan and bring the scale into balance with the tare weight on the upper beam. Place the 10-gram weight on the left hand scale pan. With the aid of the steel spatula, weigh 10 grams of the butter sample directly, and as quickly as possible into the aluminum cup on the right hand scale pan.

With the crucible tongs place aluminum cup on electric hot plate, or on tripod over gas or alcohol flame. In case of electric hot plate, use low heat to avoid burning. The temperature should not exceed 300° F. Rotate the cup with tongs at intervals to break up foam, to avoid sputtering, and to permit inspection of color. Continue heating until frothing has ceased and an amber color is obtained, with the curd a light brown.

Cool the cup to room temperature. The cooling may be hastened by setting the cup upon a coarse-mesh (½-inch mesh) wire screen with small motor fan underneath, or by setting the cup on a water-cooled metal surface, or by dipping the cup with the prongs into cool water provided that the necessary precautions are taken to wipe the cup thoroughly dry before the second weighing.

Reweigh the cooled cup by moving the rider on the lower beam to the 10% mark, and the upper rider to the point of correct balance. Read the percentage of moisture direct from both beams.

Where other than a ten-gram sample of butter is used the per cent moisture is calculated as follows:

$$\frac{\text{Weight before evaporation}-\text{Weight after evaporation}}{\text{Weight of butter used}} \times 100 = \text{per cent moisture}$$

DETERMINATION OF FAT

Apparatus and Reagents.—

Glass stirring rod, rubber tipped.
Petroleum ether, specific gravity .634 to .66 at 77° F.

Determination—Warm the aluminum cup containing the residue from the moisture test, add approximately 100 cc. of petroleum ether and stir thoroughly with the glass rod. Then remove glass rod and allow the cup to rest in tilted position for four minutes. This will permit the solids (curd and salt) to settle out. The tilted position will minimize their disturbance during subsequent decanting.

Now gently decant the petroleum ether solution of the fat, taking care not to disturb the solids which have settled. Repeat the extraction, using 50 cc. of petroleum ether. After the second decantation, warm the aluminum cup slowly to evaporate the remnant of fat solvent. Do not heat to high temperature as this would cause sputtering and loss of curd. Avoid use of an open flame in connection with petroleum ether. Continue heating until residue in cup assumes a uniform powdery form and is free from the ether odor.

Now cool the aluminum cup as directed under moisture determination, and reweigh. In the case of the special balance No. 1735, move the lower rider on the balance to the 90% mark

and move the upper rider until the scale is in balance. The total of the readings shown on these two beams gives directly the sum of the percentages of fat and of moisture. The per cent of fat, therefore, is determined by deducting the per cent of moisture from the scale reading.

Example:

Assuming that the first weighing (moisture determination) was 15.9% and the second weighing (fat determination) was 96.4%, the calculations are as follows:

Second weighing	96.4%	(sum of fat and moisture)
First weighing	15.9%	(moisture)
Difference	80.5%	(butter fat)

Where other than a ten-gram sample of butter is used the per cent fat is calculated as follows:

$$\frac{\text{Weight before extraction} - \text{Weight after extraction}}{\text{Weight of butter used}} \times 100 = \%\ \text{fat}$$

DETERMINATION OF SALT

Principle of Salt Tests.—In the operation of the salt test of butter two chemicals are used, namely silver nitrate ($AgNO_3$) and potassium chromate (K_2CrO_4). The silver nitrate has the power of chemically acting on both the salt or sodium chloride ($NaCl$), and the potassium chromate. With sodium chloride the silver nitrate forms silver chloride which is a white precipitate. With the potassium chromate the silver nitrate forms silver chromate which is a brick-red precipitate. The silver nitrate acts first on the sodium chloride. Hence, when silver nitrate is added to a solution of sodium chloride (salt) which contains some potassium chromate, the silver nitrate first combines with the sodium chloride until all the chloride is used up and has been converted into silver chloride. This precipitate is white. Now, if more silver nitrate is added, the silver combines with the chromate, changing the color of the precipitate to red. The moment the red color becomes permanent, therefore, all the salt has been neutralized, and the amount of silver nitrate required to produce this red color furnishes the basis for the calculation of the per cent of salt in butter.

The salt test is so arranged that, when a 10-gram sample of butter is used, 1 cc. of the $AgNO_3$ solution represents 1% of salt in the butter. This is based on the following calculations:

Molecular weight of $AgNO_3$ = 169.89
Molecular weight of NaCl = 58.46

To neutralize 1 gram NaCl requires $\frac{169.89}{58.46} = 2.906$ grams $AgNO_3$.

1 cc. of $AgNO_3$ solution containing 29.06 grams $AgNO_3$ in 1 liter water $\left(\frac{29.06}{1000}\right)$, will neutralize $\frac{10}{1000}$, or .01 gram, or 1% salt.

In the salt test in which 10 grams of butter are used, the sample after melting, is made up to 250 cc. of solution (other than fat). Of this solution 25 cc., or $\frac{1}{10}$ of the sample of butter, is used for the test. Since each cc. $AgNO_3$ solution neutralizes .01 gram salt, 1 cc. $AgNO_3$ solution represents $\frac{.01 \times 10}{10} \times 100 =$ 1% salt. Therefore, $\frac{\text{cc. } AgNO_3 \text{ solution required} \times 10}{10} = \%$ salt.

Where other than a 10-gram sample of butter is used, the per cent salt is calculated as follows:

$$\frac{\text{cc. } AgNO_3 \text{ solution required} \times 10}{\text{Weight of butter used}} = \% \text{ salt.}$$

Apparatus and Reagents.—

50 cc. burette with stand, or automatic type flask, burette and syphon connections, such as Nafis.
250 cc. volumetric flask.
25 cc. pipette.
White cup, stirring rod.
Silver nitrate solution, prepared by dissolving 29.064 grams of pure silver nitrate crystals in distilled water and making up one liter.
Potassium chromate indicator, consisting of a 5% solution of potassium chromate in distilled water.

Determination.—Rinse the powdery residue of the fat determination, which is in the aluminum cup, into the 250 cc. flask, using three separate rinsings, requiring in all about 100 cc. of warm distilled water. Mix thoroughly by inverting the flask several times. With the 25 cc. pipette, transfer 25 cc. of this solution to the white cup. Add 6 to 8 drops of potassium chromate indicator. Titrate slowly with the silver nitrate solu-

tion from the burette, stirring constantly with the glass rod, until the orange colored (light brick red) precipitate appears to become permanent. Do not continue the addition of silver nitrate solution until the color is red. This color is beyond the end point. Aim to stop at the first permanent orange color The number of cc. silver nitrate solution used, as obtained by the reading of the burette, indicates the percentage of salt in the butter.

In case the fat determination is omitted, the salt determination is made from the residue of the moisture determination. In such case the residue in the aluminum cup is rinsed into the 250 cc. flask, as previously directed, and enough chlorine-free (distilled) water is added to raise the bottom of the fat column to the 250 cc. mark. The test is then continued and the per cent salt read from the burette as above directed. Assuming that 2.9 cc. of silver nitrate solution were required, the butter then contains 2.9% salt.

DETERMINATION OF CURD

The curd content of butter is determined by difference. Subtract the sum of the percentages of moisture, fat and salt from 100.

Example—

Moisture was	15.9%
Fat was	80.5%
Salt was	2.9%
Total	99.3%

100 — 99.3 = 0.7% curd.

TESTING THE STRENGTH OF THE SILVER NITRATE SOLUTION USED FOR THE SALT TEST

In order to insure accurate salt determinations it is advisable to check the strength of the silver nitrate solution. This should be done when using a new solution and at reasonable intervals (once per week) thereafter, as follows:

Reagent Needed.—

Standard salt solution consisting of 10 grams of C. P. anhydrous salt made up to 1 liter with distilled water. Each cc. of

this salt solution will neutralize 1 cc. of the standard silver nitrate solution.

Making the Test.—

With a dry 10 cc. pipette transfer 10 cc. of the standard salt solution to the white cup. Add a few drops of potassium chromate indicator. Run the silver nitrate solution slowly from

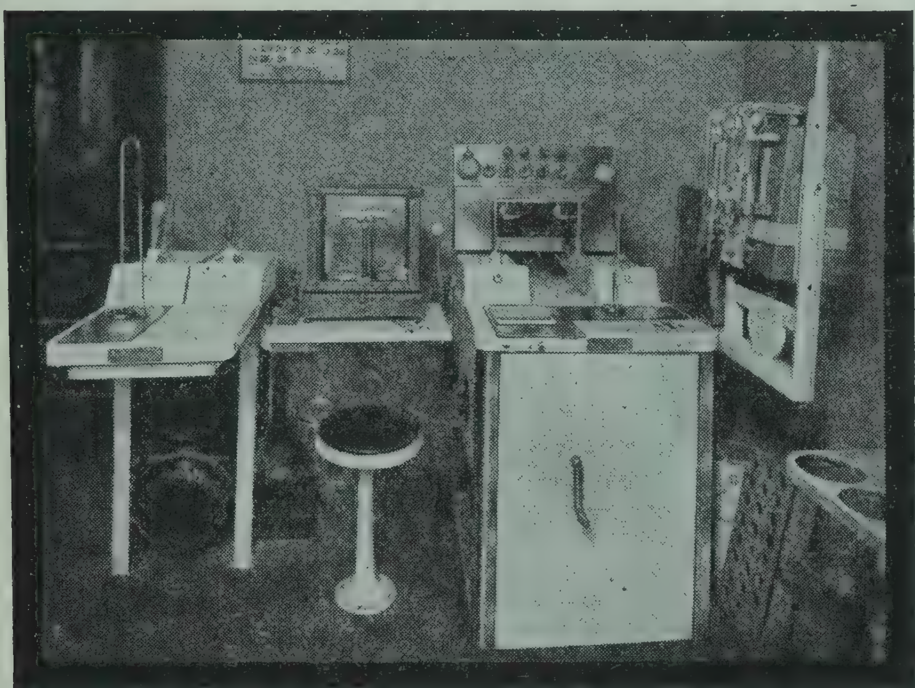


Fig. 135. Mojonnier tester for Dairy Products
Courtesy of Mojonnier Bros. Co.

the burette until the end point—the first permanent orange color—is reached. For the correct strength of the silver nitrate solution, 10 cc. are required to change the color of the 10 cc. standard salt solution to a permanent orange color. If the titration requires less than 9.5 cc., or more than 10.5 cc. of silver nitrate solution, mix the silver nitrate solution thoroughly and titrate again. If the tritration is still outside of the above range, discard the solution and make up or purchase a new one.

THE SEDIMENT TEST OF CREAM AND BUTTER*

The sediment test consists of filtering a specified amount of the fluid milk product through a special cotton or lintine filter disc. The filtering area is confined to a circular area one inch in diameter. In the case of sour cream a solvent of the curd is used to facilitate filtration. The solvents that have been tried are alkalies such as sodium bicarbonate, carbonate or hydroxide (lye), or ammonia, and acid, such as hydrochloric acid. In the case of butter, the most common reagents that have been used are hot water, bicarbonate of soda, borax, and hydrochloric acid.

For both sour cream and butter, the acid method has been found the most suitable, as shown by the work of Stewart.[2]

The sediment testing, particularly of cream and butter, has been given years of study by the American Butter Institute under the direction of its executive secretary, Dr. H. W. Hepburn. These efforts have resulted in standardizing the method. The specifications for sediment tests recorded here are, therefore, essentially those given by the American Butter Institute, in their Laboratory Manual, copyrighted in 1937.

APPARATUS AND REAGENTS

Sediment tester with 1 inch dia. effective filtering surface.
Standard lintine discs, 1¼ inch dia.
Electric hot plate or small gas heater.
Enamelware container, 400 cc. capacity.
Quart milk bottle or sample jar.
Sample jar 8 ounce capacity.
Sample jar 2 ounce capacity.
Dairy thermometer (about 40 to 220° F.).
Heavy stirring rod or spoon.
White mounting paper or card board inserts.
Glassine or cellophane envelopes.
Metal forceps.
Absorbent paper towel,
Water bath.
Hydrochloric Acid (concentrated C. P.).
Filtered water.

DETERMINATION

Sediment Testing of Sweet Cream.—Stir cream in can thoroughly. Take a one quart sample in a suitable container and warm to 85 to 90° F., stirring constantly. Transfer 2 ounces of the warmed cream to the 400 cc. container. Add 8 ounces of filtered hot water (180° F.) and stir thoroughly.

Pour the warm mixture of cream and water into the sediment tester (which has previously been thoroughly rinsed with filtered water and to which has been affixed a clean, standard lintine disc), and force through. Then rinse sediment tester by forcing through at least 4 ounces of filtered hot water (180° F.), before removing the soiled lintine disc.

With metal forceps remove the soiled lintine disc, place it, with soiled side up, on an absorbent paper towel, allowing excess moisture to be absorbed. Cover the soiled disc with another absorbent paper in such a manner as to permit no contact. This serves to prevent alteration of its rating while drying. The soiled lintine disc (free from excess moisture) is then mounted on white paper, or fastened to a cardboard insert, sealed in a glassine or cellophane envelope.

Sediment Testing of Sour Cream.—Proceed as directed for "Sweet Cream," except that 8 ounces of hot hydrochloric acid solution (180° F.) are added to the 2 ounce sample of cream instead of hot, filtered water. The hydrochloric acid solution is prepared by adding 3.2 cc. concentrated C. P. HCl to 1000 cc. of filtered, distilled water.

Sediment Testing of Butter.—Use either the hot water method or the acid method described below:

HOT WATER METHOD

Place ¼ pound of butter in a clean enamelware container. Add 8 ounces of hot, filtered water (180° F.) and heat the mixture on the water bath to 165° F., stirring thoroughly to insure complete mixing and melting of the butter.

Force the heated mixture through the sediment tester (which has previously been thoroughly rinsed with filtered water and to which has been affixed a clean, standard lintine disc). Then rinse the sediment tester thoroughly by forcing through at least 4 ounces of hot, filtered water (180° F.) before removing the lintine disc.

ACID METHOD

Proceed as in the "Hot Water Method," except that 200 cc. of hot, filtered hydrochloric acid solution (180° F.) are added to the ¼ pound butter sample in the clean enamelware container, instead of 8 ounces of hot, filtered water. The hydrochloric acid solution is prepared by adding 3.2 cc. concentrated C. P. HCl to 1000 cc. of filtered, distilled water.

Disposition of Sediment Discs.—In the case of sediment tests of cream, examination of the discs reveals the relative

freedom from extraneous matter of cream from individual cans. In case of unclean discs it gives the creamery opportunity to take the necessary steps to improve its cream supply. In order to derive the maximum benefit from the sediment testing of cream, the sediment discs should be brought to the attention of the patrons by either posting them on a board in the creamery where the patrons can see them, or by sending them to the patrons.

Sediment tests of butter supply the creamery with information regarding the relative freedom of its butter from foreign matter. If the discs are examined under magnification, the character of foreign matter may be revealed.

Numerical Ratings of Sediment Discs.—The American Butter Institute recommends the classifying of sediment discs of cream and of butter on the basis of the same or similar numerical ratings as are used with the Connecticut Official Milk Sediment Standards (1931), which are as follows:

0 = Clean	75 = Slightly dirty
25 = Fairly clean	100 = Dirty
50 = Acceptable	125 = Very dirty

DETECTION OF MINERAL OIL IN CREAM

The adulteration of cream with mineral oil involves serious loss to the creamery. While occurrences of such adulteration are comparatively rare, they are of sufficient importance to justify recognition of their menace. Cream containing mineral oil will decrease the overrun. The mineral oil increases the fat test of the cream. The bulk of the mineral oil that has been added to the cream passes into the buttermilk, increasing the buttermilk test. Yet butter made from such cream also shows the presence of a small amount of mineral oil and such butter is declared illegal by the Federal Food and Drugs Administration.

It is practically impossible to detect the presence of mineral oil in the routine procedure of cream grading, but it can readily be determined by a simple test of the fat from the test bottle of the finished cream test. This test is based on the fact that the fatty acids of butter fat form soap with the alcoholic caustic used in the test. The mineral oil does not saponify. When

distilled water is added, the mineral oil emulsifies with the water in the presence of the soap, yielding a turbid liquid.

Apparatus and Reagents Needed.—

1 cc. pipette
25 cc. pipette
½ pint milk bottle, or similar container
Caustic alcohol, made up as follows:

Pure grain alcohol	98%	
Sodium hydroxide	2%	
Total	100%	caustic alcohol

Determination.—

1. Use butter fat from the cream test bottle before glymol has been added.

2. With the 1 cc. pipette transfer 1 cc. of the fat from the cream test bottle into a ½ pint milk bottle. This bottle must be thoroughly clean.

3. Add 25 cc. of caustic alcohol to the fat in the milk bottle.

4. Set the milk bottle containing the mixture of fat and caustic alcohol into a water bath at 172° F. Hold it there for 10 minutes, then shake to mix thoroughly, and return to the water bath at the same temperature for another 10 minutes.

5. Remove from water bath and add 25 cc. of distilled water at ordinary temperature.

6. If no mineral oil is present, the solution in the milk bottle remains perfectly clear. If mineral oil is present the solution becomes turbid immediately. As little as 0.5% mineral oil in the cream will yield a turbid test by this method.

DETERMINATION OF KEEPING QUALITY OF BUTTER

Practical factory tests for the determination of the keeping quality of butter are limited principally to incubation tests and tests for acidity. Incubation tests assist in revealing the presence or absence of the tendency for flavor deterioration due to bacterial causes. Acidity tests of butter indicate the approximate churning acidity, which in turn has been found to be one of the controlling factors of butter deterioration due to chemical reactions.

INCUBATION TESTS

There are principally two kinds of incubation tests that have been found useful as indices to the keeping quality of butter, namely, the eight-day incubation test and the rapid incubation test.

Eight-Day Incubation Test.—Score the butter to be tested and record the score. Fill a clean, sterile, two ounce, screw top glass jar solidly to within about one-half inch of the top with butter from the churn, or from the finished package, using a sterile spatula or table knife. Seal the jar and store it at a uniform temperature of 70° F. for eight days. Then place it in the cooler (at about 50° F.) over night. Rescore the sample the following day. Compare this score with the original score and observe the character of flavor deterioration, if any. Absence of off-flavor at the time of rescoring is suggestive of normal keeping quality.

Rapid Incubation Test, or Bottle Test.—Place a small amount (about 20 to 30 grams) of the butter to be tested into a sterile, two ounce jar, seal and place at room temperature or slightly higher (70 to 90° F.). At intervals of about 24 hours note the odor in the jar. Absence of objectionable odor by the fourth day of incubation, is a reasonably dependable indication of absence of damaging bacterial contamination. This may be further verified by extending the incubation period to six days. The results are materially expedited by melting the butter sample. This is best done by setting the sealed jar into a water bath at 95 to 100° F. until melted, and then incubating as above directed.

The advantage of this test lies in its relatively rapid detection of contamination with specific flavor-damaging organisms, such as tends to lead to rancid and putrid flavor and odor. In most cases of bottle tests in which the butter is melted at the beginning of incubation, the off-odor, if any, will develop within 24 to 48 hours. This test is especially valuable in efforts to promptly locate the cause of the defect, in the case of creameries that are beset with the menace of these disastrous off-flavors in their butter. The periodic testing of samples in this manner further assists in avoiding costly epidemics of butter spoilage due to bacterial causes.

ACID TESTS OF BUTTER

To this group of keeping quality indices belong tests of the titratable acidity and determinations of the pH of butter. They may serve to indicate the tendency of butter to yield to flavor deterioration caused by chemical reactions. Their merit depends in a large measure on their relation to the churning acidity of the cream, which has been found the most dependable factor in the control of keeping quality from the standpoint of chemical changes in the butter.

TEST FOR TITRATABLE ACIDITY

Nissen[3] who made an extensive study of suitable tests for the titratable acidity of butter, found the following method of determination reasonably dependable:

Determination.—Use 18 grams of butter and $\frac{N}{50}$ solution of sodium hydroxide. Weigh the butter into the titrating cup and add 90 cc. of previously boiled distilled water, cooled to about 150° F. Add 1 cc. of phenolphthalein indicator and titrate. Add the alkali solution fairly rapidly until a reasonably permanent pink color is obtained. This will usually require about one-half minute. Upon continued stirring the end point will fade. Continue the addition of alkali solution in small quantities, and the agitation, until 3 minutes have been consumed in all. Only enough additional alkali solution is added during the final stirring to maintain the light pink color of the mixture fairly uniform. A light definite pink color should then be evident in the watery portion when the fat rises upon discontinuing the agitation. The tendency for the pink color to fade out renders recognition of the final end point somewhat uncertain. It is for this reason that the 3 minute titration period is recommended.

When calculated as lactic acid, each cc. $\frac{N}{50}$ alkali solution is equal to 0.01% acid, as explained by the following calculation.

1 cc. $\frac{N}{50}$ alkali solution neutralizes $\frac{.09}{50} = 0.0018$ gram acid

$$\frac{\text{cc. alkali sol.} \times .0018}{18} \times 100 = \%\ \text{lactic acid.}$$

Example:

If 5 cc. alkali solution are required, the per cent acid of the butter is $\frac{5 \times .0018}{18} \times 100 = 0.05\%$ acid.

The work of Hunziker, Cordes and Nissen[4] shows approximately the following relationship of titrable acidity of butter to churning acidity of cream.

Churning Acidity of Cream	Titratable Acidity of Butter
0.15%	0.02 to 0.04%
0.25%	0.03 to 0.05%
0.30%	0.05 to 0.07%
0.50%	0.08 to 0.12%
0.80%	0.13 to 0.20%

The above figures should not be considered in the light of a rigid scale of comparison. They represent the maximum range of titratable acidity of butter made from individual churnings of sweet cream (32.5% fat) and of the same sweet cream ripened to different acidities. They may serve, however, to give an idea of the general direction of the relation of titratable acidity of butter and churning acidity of cream.

For satisfactory keeping quality of butter from the standpoint of absence of chemical flavor deterioration due to acidity, the titratable acidity of salted butter should not exceed from 0.05 to 0.06%. Lower acidities are preferable. In the absence of salt, chemical deterioration due to acidity is negligible. Unsalted butter made from ripened cream usually has an acidity of about 0.12 to 0.15%. This acidity does not jeopardize its keeping quality, in fact it tends to improve the keeping quality of unsalted butter, due to its retarding effect on bacterial activity damaging to flavor.

THE pH OF BUTTER

Determinations of the pH of butter have also been found useful under certain conditions, in efforts to predict the keeping quality of butter, relative to the tendency of flavor deterioration due to chemical reactions.

The pH value is a measure of the active acid, or the concentration of hydrogen ions. The principle of all acid solutions depends on the presence of hydrogen ions. The true or active acidity is based on the concentration of hydrogen ions, the measurement of which expresses the degree of ionization. While the titratable acidity records the volume of acid present in a

given volume of sample, the hydrogen ion concentration is a measure of the intensity of the acidity.

In cream, for instance, the acid is concentrated in the cream serum. The pH of cream is a direct measure of the acidity of the cream serum. The titratable acidity of the cream is not a direct measure of the serum acidity. The relationship between titratable acidity and cream serum acidity varies with diverse factors, primarily with the richness of the cream (or the proportion of cream serum present).

Likewise, the pH of the butter serum corresponds closely with the pH of the cream. Experiments by Hunziker, Cordes and Nissen, covering 45 individual churnings and representing churning acidities ranging from 0.15% to 0.80%, yielded an average cream pH of 6.06 and an average butter pH of 6.10.

Mechanism of the Symbol "pH."—In general, the hydrogen ion concentration of acid solutions is so small that it constitutes, and can be expressed only in terms of very small fractions. Thus, a weak acid reaction may show a hydrogen ion concentration of 0.000,001, i.e., one liter of this weak acid solution contains 0.000,001 gram of hydrogen ions. The hydrogen ion concentration is, therefore, usually not expressed in terms of a normal solution of hydrogen ions, but in more simplified form, such as by the symbol pH, which has a range of values extending from 0 to 14.

The symbol pH is a technical term which has come to mean the exponent of ten with a negative sign, which expresses the gram ions of hydrogen per liter. The letter p refers to potential and the letter H to hydrogen ion concentration. The purpose of the arrangement of the symbol as "pH" is to distinguish it from the standard abbreviation of the word phenol, which is Ph. The following example may serve to illustrate the value of the symbol pH:

Pure water, which is considered neutral, has a hydrogen ion concentration of 1×10^{-7}, or 0.000,000,1. In order to avoid this long figure, the logarithm of the reciprocal of this figure is taken, which is 7.0. Pure water has a pH of 7. The figure 7 represents the neutral point in the pH scale. Assuming now that the hydrogen ion concentration is increased 10 times that of water, it would then be 1×10^{-6}, or 0.000,001. The logarithm of the reciprocal of this figure is 6. In this case the pH value is 6.

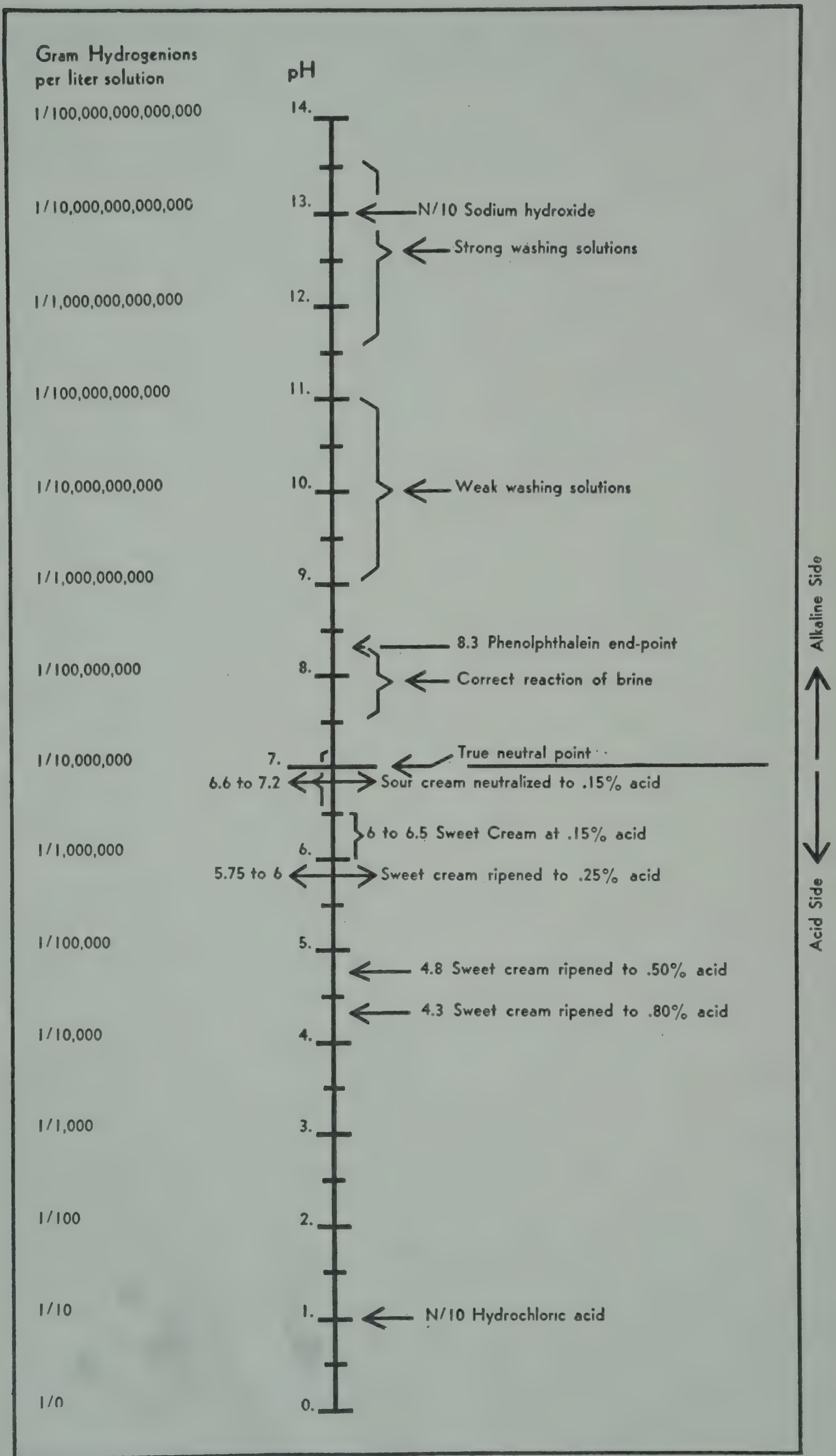


Fig. 136. pH chart for creamery use

These illustrations show that as the true acidity (hydrogen ion concentration) increases, the pH value drops. This is further illustrated in the graph of Fig. 136.

At the present stage of hydrogen ion concentration measurements, the pH is determined either by the electro-metric method or by the colorimetric method.

Electrometric Method.—The electrometric method has to do with the measurement of the potential attained by the use of certain electrodes when placed in a solution. The potential is dependent on the hydrogen ion concentration of the solution. Of the several kinds of electrodes that may be used for the determination of the pH, the quinhydrone electrode and the glass electrode are most commonly employed at present in connection with dairy products. From the potential obtained the hydrogen ion concentration may be calculated with the help of formula, or the pH value may be taken direct from tables available for this purpose. The pH apparatus is usually accompanied by directions for operation from the manufacturer.

Preparation of Butter Sample for Electrometric pH Determination.—Use only fat-free serum of the butter. The butter sample must be prepared in a manner that will prevent progressive development of acidity prior to the test, and that will yield a serum that is free from fat, and in which the curd has been retained in such condition that it mixes readily with the remainder of the serum. The modification by Weckel,[5] of the method developed by Hunziker, Cordes and Nissen[4] has been found to meet these requirements satisfactorily.

Transfer about 35 grams of a well mixed sample of butter to a test tube (dia. 2.5 cm. and length 12 cm.). Warm contents in water bath at 140° F. Whirl in Mojonnier centrifuge rack, or in Babcock tester by placing the test tube supported by a cork in the test bottle cup. Whirl 2 to 3 minutes at 200 r.p.m. in an 18 inch centrifuge. (1) Withdraw as much of the fat-free serum as possible for the pH determination by means of a pipette inserted through the fat layer. Or (2) chill the contents of the test tube in cold water until the fatty layer has solidified. Then shake the inverted tube to insure complete mixture of its contents and withdraw as much of the fat-free serum as possible for the pH determination by plunging a pipette through the solidified layer.

Colorimetric Method.—The colorimetric method consists of the use of certain color indicators which are added to the liquid to be tested, and which, according to the active acid present in the solution, assume different colors. Each indicator yields its own specific color for each pH value and covers its own particular range of pH values. To a measured amount of the liquid to be tested (in this case butter serum) a certain amount of indicator solution of specified concentration is added, and the resulting color is compared with a color standard that shows the pH value for each color.

The range of pH values encountered in butter is covered fairly adequately by such indicators as Brom thymol blue, and by Alizarin. Their pH range and the color shades of different pH values within their respective range, are listed in Table 82

Table 82. Indicators for Colorimetric pH Determination of Butter

Brom Thymol Blue		Alizarin	
pH Value	Shade of Color	pH Value	Shade of Color
6.0, or less	Yellow	4.5	Yellow
6.6	Greenish Yellow	5.2	Brownish Yellow
6.8	Yellowish Green	5.7	Yellowish Brown
7.0	Green	5.95	Brown
7.2	Bluish Green	6.15	Reddish Brown
7.6, or more	Blue	6.30	Brownish Red
		6.45	Pale Red
		6.65	Lilac
		7.0	Violet

Determination (Colorimetrically).—To a 30 cc. beaker add about 15 cc. distilled water and about 10 grams of the butter to be tested. Bring the mixture to a boil. Now add to a small test tube 4 to 5 drops of the indicator and 1 cc. of the serum from the melted butter sample in the beaker. Compare the color of the contents of the test tube with the color chart for the respective indicator.

The above method yields a fairly close approximation of the electrometrically determined pH. It is not infallible as to accuracy, but because of its simplicity, requiring no special apparatus nor technical skill, it has been found a practical means of estimating the approximate pH of butter.

Merit of pH Determinations of Butter.—As explained in earlier paragraphs, and also in Chapter XXI under Acidity of Butter, the optimum range of pH for chemical stability (keeping quality) of butter varies with the character of cream from which the butter is made.

Because of these facts, pH determinations of butter of unknown origin, are of limited value only, while pH determinations of butter for factory use do provide a fairly dependable check on its probable keeping quality.

Bacteriological Analysis of Butter.—For approved methods for the bacteriological examination of butter the reader is referred to standard works on bacteriological procedure in general, and in particular to "Standard Methods of Milk Analysis," 7th Edition, published by the American Public Health Association, New York, and to "The Microbiological Analysis of Butter," Journal of Dairy Science XVI No. 3, 1933, published by the American Dairy Science Association, Columbus, Ohio.

REFERENCES

1. HUNZIKER, O. F., SPITZER, GEO., and MILLS, H. C., Purdue Agr. Expt. Sta. Bul. 145, (1910).
2. STEWART, G. F., J. D. Sc. XX, *8*, 509, (1937).
3. NISSEN, B. H., Ind. and Eng. Chem. III, 374, (1931).
4. HUNZIKER, O. F., CORDES, W. A., and NISSEN, B. H., J. D. Sc. XIV, 347, (1931).
5. WECKEL, K. G., J. D. Sc. XVI, *3*, 249, (1933).

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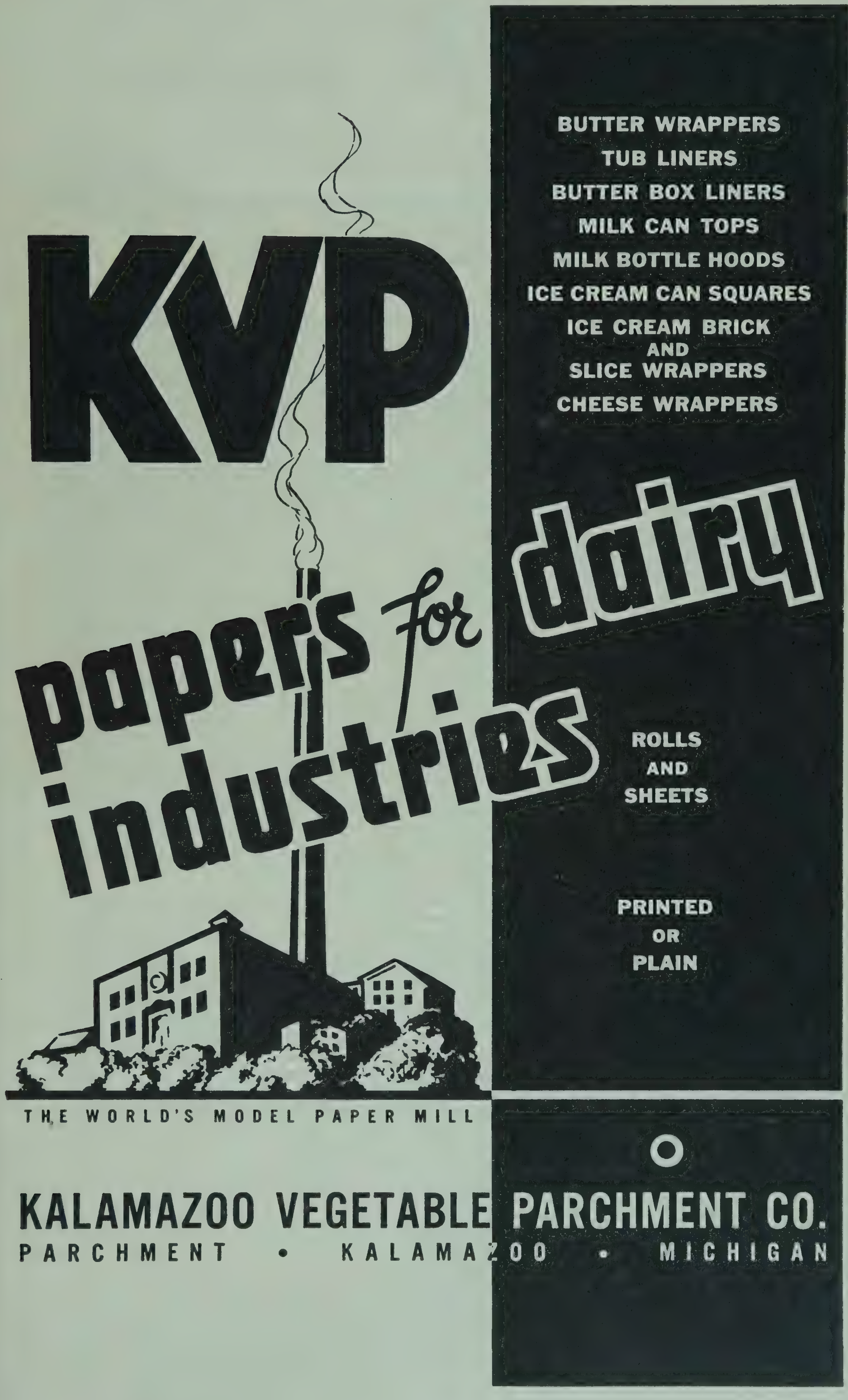
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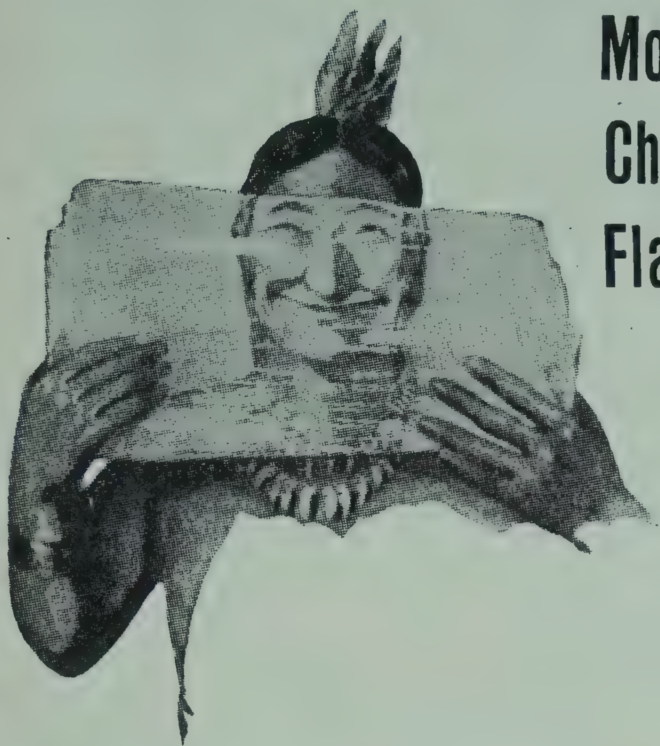

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